INTEGRATION OF CIRCULATION DATA IN THE BEAUFORT SEA

by

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ABSTRACT

Wind and oceanographic data from the nearshore area of the Beaufort Sea along the north coast of Alaska between Pt. Barrow and Demarcation Point were identified, catalogued, and, where possible, acquired. Selected current records from several different years were analyzed, and the relation between winds and nearshore currents and between nearshore and offshore (represented by Beaufort Sea Mesoscale Circulation Study) currents was investigated. Nearshore current records were from the open water season and primarily from depths of 6 m or less. Current meter data obtained shoreward of the barrier islands were excluded from the analysis because of shallowness and the sheltering effects of the islands.

A total of 56 data sets, collected during the period 1948-1989, were cataloged. Of these, 29 data sets (some incomplete) were acquired and incorporated into the project data base. The bulk of data acquired was from oil company sponsored studies in the Prudhoe Bay/Stefansson Sound region. NODC provided additional data sets. Attempts to acquire the remaining data sets were unsuccessful due to proprietary constraints and data inaccessibility.

Complex regression analyses showed that the wind accounted for approximately 40 to 50 percent of the variance of the nearshore currents measured at sensor depths of 3 m or less, and markedly less at sensor depths greater than 3 m. Comparison of Current records frail similar locations and depths indicated comparable wind-explained variance from year-to-year. Current direction was strongly rectified by bottom topography and proximity to the coastline. Current fluctuations consistently lagged the wind by one to three hours. Current spectra were often inconclusive, but generally indicated energy in the 3- to 8-day period range, which includes meteorological time scales. Tides did not constitute a significant source of signal variance. Current records were not adequate to identify and study other potential sources of current variability such as trapped waves or instabilities.

Comparisons between nearshore and offshore open water currents were limited by the very small number of current meter pairs available. In one comparison of 1987 data, nearshore currents were highly Correlated (r=0. 66) with currents 70 km offshore and led offshore currents by 14 hours. The highest coherence between the currents was at a frequency of 0.0274 cph (37-hour period). For the period from late July to early September 1987, the nearshore currents were highly correlated with Resolution Island winds (r=0.91 at lag=2 hours), while the offshore currents were less strongly correlated with the winds (r=0.69 at lag=16 hums). It is not clear whether the nearshore/offshore Current correlation in this particular case was due to direct wind forcing of both orto a combination of direct and indirect meteorological forcing. While the periodicity of 37 hours for maximum coherence seems short for atmospheric phenomena, no other dynamic mechanism is evident from the data.

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CONTENTS, continued.

*Appendix A (one volume) and Appendix B (two volumes) are not included in this publication. Copies are on file at the NOAA, OAD Alaska Office, Anchorage, and NTIS, 5285 Port Royal Road, Springfield, VA 22161.

<u>FIGURES</u>

FIGURES, *continued.*

FIGURES, continued.

TABLES

1.0 INTRODUCTION

1.1 OBJECTIVES

Exploration and production of oil from lease-sale areas off the north coast of Alaska have prompted a large number of studies of the Beaufort Sea environment by both government and private industry. As a result of these investigations, a significant oceanographic database exists for the nearshore Beaufort sea (depths <20m) as well as for regions farther offshore over the shelf and slope. Results of the recently-completed Beaufort sea Mesoscale Circulation Study (BSMCS) (Aagaard et al., 1989) provide a valuable contribution to the database and to knowledge of long-term, synoptic ocean circulation and relation to the wind beyond the nearshore area. While the BSMCS data have been analyzed and interpreted, much of the data from the nearshore area was collected for descriptive purposes and has not been subjected to rigorous analysis.

The first objective of this work is to identify and compile existing current meter, hydrographic, and meteorological data from the nearshore area of the Beaufort sea. The second is to analyze existing datato investigate the relation between currents in the nearshore area and winds. The third is to relate the nearshore circulation results with those of the offshore-oriented BSMCS. The area of study extends from Point Barrow, Alaska to Demarcation Point (see Figure 2-1).

1.2 GENERAL COASTAL CURRENT REGIME

Aagaard (1984) examined circulation over the shelf and slope of the southern Beaufort Sea and included a brief background description of the coastal current regime. The description presented here draws heavily from Aagaard (1984) and is meant to provide a context for considering the results of various analyses detailed in this report.

There is ample evidence of wind-driven circulation in the inner shelf area, particularly during summer. In general, water movement is westward under the influence of easterly winds, although fluctuations in current direction reflect fluctuations in wind direction. Nearshore circulation also responds to seasonal riverine input during the warm season and brine rejection during the cold part of the year, and the resulting density-driven currents modify the wind-driven circulation and circulation due to large-scale pressure gradients.

Presence of ice cover suppresses kinetic energy levels in currents over the inner shelf relative to those in summer during open water. Even so, there appears to be a weak meteorologically-driven flow component during winter. This flow component is likely a Combination of direct wind stress and coastal setup.

Seaward of approximately the 50-m isobath is a relatively strong eastward current that Aagaard (1984) terms "the Beaufort undercurrent." It is speculated that the flow extends from the near surface to the bottom between the 50-- 2500-m isobaths. The surface circulation is of mean westward motion and represents the southern edge of the anticylonic gyre in the Canadian Basin of the Arctic mean.

Previous investigations have not detailed the transition and communication between the inshore or nearshore regime and circulation farther offshore. The encroachment of ice remains a formidable obstacle to obtaining adequate data records. A small number of individual current records indicate substantial cross isobath water motions between the offshore and nearshore regimes, so that there is potential for exchange between the two regimes.

1.3 ORGANIZATION OF THIS REPORT

The structure of this report reflects the near-independence of the three objectives. Three primary sections describe the work associated with the three objectives and are intended to stand alone, largely independent of each other. Within each respective section, methods, results and discussion, and other pertinent details are presented. The comprehensive summary condenses the results of all three project aspects, and a short Recommendations section follows.

2.0 DATA IDENTIFICATION, DOCUMENTATION, COMPILATION, AND EVALUATION

2.1 METHODS

2.1.1 Data Identification

This element of the program included a comprehensive review of oceanographic literature, project reports, data reports, and existing published data inventories for the nearshore Alaska Beaufort Sea region. Basic procedures involved manual and automated literature searches, and direct inquiries to appropriate investigators, agencies (federal, state, and local), academic institutions, and private organizations (e.g., oil companies, consulting firms) known to have conducted studies in the region. More than 150 published and unpublished references were screened as possible sources of information on historical data sets. From all of these sources, a list of past experiments in the region was generated, and served to target the data sets to be sought for incorporation into the project data base. Approximately 80 references containing relevant information on the data sets uncovered in this search are listed in Section 8.0. An additional useful resource in this task was an arctic data compilation and appraisal report prepared by the Canadian Institute of Ocean Sciences (IOS) (Birch et al., 1984).

2.1.2 Data Documentation

The data documentation step included acquisition of information on where, when, why, how, and by whom individual data sets were collected. For each of the data sets identified, all available information of this type was extracted from the reference material or via direct contact with the original investigator(s). A series of standardized data set documentation forms was used to record the information. Individual data sets were inventoried according to location within the study region and types of data collected, as described below.

Although NOAA's primary interest in this program was the integration of historical measurements inshore of the 20 m isobath, a larger area encompassing the entire Alaskan Beaufort Sea continental shelf was adopted in the identification and documentation phases of the study (Figure 2-1). This was done because the nearshore measurements were often part of larger scale continental shelf experiments, and it was felt that without the entire picture, the relevance of certain data sets might be lost. Five subregions within the overall study area were defined for the purpose of documenting the location of data collected in past experiments. These subregions were delineated partly on the basis of geographic features (i.e., major bays and capes), and partly on the basis of known concentrations of past oceanographic activity.

Data types documented included current meter (moored and profiling), Lagrangian drifter, hy[illegible]hic (temperature and salinity), sea level (tide gauge), and meteorologic. For sea level and meteorologic data, only those data sets from temporary stations installed as part of discrete experiments were documented in this study (i.e., long-term station data from permanent weather stations or NOS tide stations were not documented).

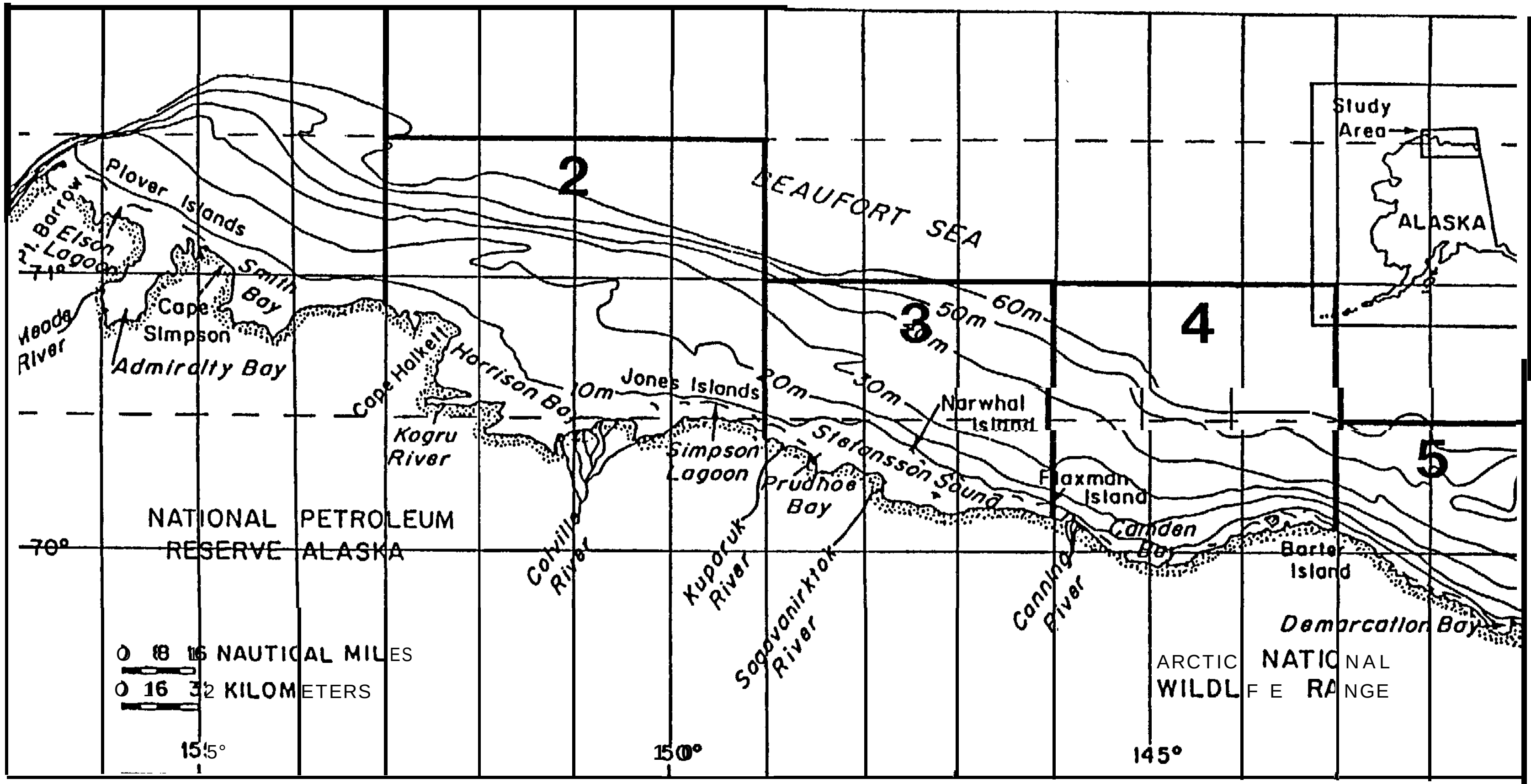


Figure 2-1. Map of the study area. Heavy lines delineate study subregions, labeled 1-5.

The final aspect of the documentation task included listing pertinent references for each data set so that subsequent investigators will be able to locate more information on a particular data set if desired. These key references were selected from the full set of references uncovered during the identification task (see section 2.1.1 above).

2.1.3 Data Compilation

Data compilation consisted of the acquisition, organization, and reformatting of all available historical data sets identified by the study. Data sets available in digital format on computer storage media were the primary target for acquisition, although in a few cases, optical scan-digitization of hardcopy tabular data listings allowed incorporation of data -- previously available on computer media.

The computer system selected for storage and manipulation of the project data base was a 386 microcomputer, equipped with a 322 megabyte hard disk and a 150 megabyte streaming tape cartridge backup system. Data received on 9-track magnetic tape were read temporarily onto a VAX 11/780 computer, then downloaded to the 386 microcomputer. Each incoming data set was reformatted to standard NODC format (if necessary), then copied into permanent data directories organized by year, experiment, and data type. The data base was periodically backed up using the cassette tape storage backup system.

Since a considerable volume of data was available from the National Oceanographic Data Center (NODC), it was decided to ship the 386 microcomputer to NODC for the purpose a direct data transfer from the NODC archives to the hard disk on the 386. Approximately 50 megabytes of data were obtained from NODC in this manner. The types of data transferred included: current meter resultants and components (file types F005 and F015), low and high resolution S/CTD (file types C002 and F002), Lagrangian drifter (file type F156), Nansen bottle cast (file type C100), sea level (pressure gauge) (file type F017), and wind (file type F191) .

A large volume of historical data from the Prudhoe Bay/Stefansson Sound region already on hand in the Ebasco Environmental data archives was transferred into the project data base, as were a number of smaller data sets acquired from individual investigators or from scan-digitization of tabular listings in reports.

Finally, although the data collected during the BSMCS appeared to be complete in the NODC holdings, a separate data transfer of all data collected during that experiment was accomplished by direct access to the NOAA/PMEL computer system. In this manner, the completeness of the BSMCS data set was assured.

The volume of oceanographic and accompanying meteorologic data from all sources acquired during the compilation phase of this program was approximately 90 megabytes.

Additional effort was expended in attempts to track down and acquire data sets not readily available from the sources noted above. Despite these efforts, many of the known historical data sets remained unavailable, due to proprietary constraints or data inaccessibility. These restrictions are discussed further in Section 2.2.

2.1.4 Data Evaluation

One of the secondary goals of Task 1 of this study was to include, with the data set documentation, a subjective estimate of the data quality (i.e., accuracy, completeness, consistency) inherent in each data set identified. A numerical data quality rating scale developed by the 10S (Birch et al., 1984) was intended for use in this effort.

Unfortunately, the unavailability of a large number of historical data sets, combined with incomplete documentation on experimental methods, data processing, and quality control on many others led us to conclude that such a numerical evaluation would be ineffective. In their arctic data inventory, Birch et al. (1984) did assign numerical ratings to each data set, but in many cases the number given was 2, which was their designation for indeterminate data quality.

During the course of the data analyses conducted in Task 2, an evaluation of each data set used was made during preparation of the data for input into the analysis routines. Some data quality problems became apparent in these evaluations. These are noted in Section 3.2.

2.2 RESULTS AND DISCUSSION

The number of data sets uncovered during the identification phase exceeded our expectations. Some of these data sets were relatively small and obscure. One cannot, however, categorize such data as insignificant, since in this data sparse region, even a limited data set may provide key information on spatial and temporal variability. Furthermore, some of these data sets were poorly documented and presumably unknown to many contemporary arctic investigators. As such, they have the potential to shed new light on results derived from more recent studies, and may guide planning efforts for future field experiments.

A total of 56 distinct project data sets encompassing physical oceanographic data from some part of the study area were identified. The earliest documented experiment occurred in 1948 and the most recent in the summer of 1989. Table 2-1 summarizes the available information on each of these data sets, including sampling areas (refer to Figure 2-1 for subregions), data types, and data status (archival status and availability). A reference is listed to direct the interested reader to a source of further information on the experiment (except in a few cases where no appropriate reference was found). For ease of association, each experiment has been named according to common usage (e.g.,

Table 2-1. Summary of project data set information. Subregion designations areas shown in Figure 2-1. Data type abbreviations areas follows: H = hydrographic, C = current meter, D = drifter, P.= current profile, M = meteorologic, S = sea level,

Project Name/Year	Reference	Subregions Sampled	Data Types	Data Status
COAST GUARD 1948*	None found	1	H	NODC; project data base
NAVY 1950'	U.S. Navy Hydrographic Office (1954)	1,2,3,4,5	H	NODC; project data base
NAVY 1951 •	Mountain (1974)	1,2,3,4,	H	NODC; project database
COAST GUARD 1955'	None found	1,3,4,5	H	NODC; project database
NAVY 1955*	U.S. Navy Hydrographic Office (1958)	1,2	H	NODC; project data base
NAVY 1956"	U.S. Navy Hydrographic Office (1960)	1,3	H	NODC; project database
NAVY 1957*	U.S. Navy Hydrographic Office (1959)	1,2,3,4,5	H	NODC; project database
NAVY 1958'	U.S. Naval Oceanographic Office (1963)	1,2,3,4,5	H	NODC; project database
NAVY 1959'	U.S. Naval Oceanographic Office (1963)	1,2,3,4	H	NODC; project database
NAVY 1960*	U.S. Naval Oceanographic Office (1964)	1,2,3,4	H	NODC; project database
PAQUETTE 1960'	Paquette and Bourke (1974)	1,2,3	H	NODC; project database
KINNEY 1968-69*	Kinney et al. (1970)	1,2,3,4	H	NODC; project data base
KINNEY/DYGAS 1970-72"	Dygas (1975)	2	C, D, M	unavailable [4]
MIZPAC 1971*	Paquette and Bourke (1974)	1,2	H, C	unavailable [3]

Project Name/Year	Reference	Subregions Sampled	Data Types	Data Status
WEBSEC 1971*	Hufford (1973)	1,2,3,4	H, C	NODC; project data base (H only)
WEBSEC 1972*	Hufford (1975)	1,2,3,4	H, C	NODC; project database (H only)
WISEMAN 1972*	Wiseman et al. (1973)	2	D, M	unavailable (4)
WEBSEC 1973*	Homer (1981)	1,2,3	H	unavailable (6)
HORNER 1974*	Homer (1981)	1,2,3,4	H	NODC; project database
BARNES (1971-76)'	Barnes et al. (1977)	2,3	H, C, S	unavailable (2)
GARRISON (1973-77)*	Garrison et al. (1979)	1,2	H	unavailable (2)
0CS1CAUAWA% 1975*	Callaway and Koblinsky (1976)	3	S	unavailable (4)
BSIMS 1975-76	Oceanographic Services Inc. (1976)	2*3	C, M	unavailable (1), (2)
OCS/AAGAARD 1975-80*	Aagaard (1984)	2,3,4,5	C, H	NODC; project database (most)
OCS/HORNER 1976-78*	Homer (1981)	1,2,3,4,5	H	unavailable (6)
OCS/CARSEY 1976"	Carsey (1 977)	1,2,3	M	NODC; project database
WEST DOCK 1978-77	Grider et al. (1978)	3	H	unavailable (6)
OCS/MATTHEWS 1977-81'	Matthews (1981)	2	H, C, P, S	NODC; project database (1977 and part of 1978 -C only) (4)
MIZPAC 1977*	Paquette and Bourke (1978)	1	H	unavailable (3)
OCS/LEAVITT 1977*	Leavitt (1 978)	2,3,4	M	NODC; project data base

Table 2-1. (continued)

Project Name/Year	Reference	Subregions Sampled	Data Types	Data Status
OCS/MUNGALL 1977*	Mungall et al. (1978)	2	H	unavailable (4)
MIZPAC 1978*	Paquette and Bourke (1979)	1	H	unavailable (3)
WEST DOCK 1978-79	Chin et al. (1979)	3	H, C, D	unavailable (4)
OCS/MUNGALL 1978*	Mungall et al. (1979)	2	H, C, D	unavailable (4)
OCS/KOZO 1978-80'	Kozo (1981)	1,2,3	M	NODC; project data base
BEAUMOP 1978-83	Oceanographic Services Inc. (1979)	3	H, C, M, S	unavailable (1),(2)
REINDEER IS. 1979	Northern Technical Services (1981)	3	H, C, M	unavailable (1)
OCS/WILSON 1979-80"	Wilson et al. (1981)	2,3	D	unavailable (2)
SAI 1980*	None found	1,2	H	unavailable (4)
MURPHY 1980-81"	Murphy et al. (1983)	3,4,5	D	unavailable (6)
GREISMAN 1981*	Greisman and Blaskovich (1984)	3,4	H, C	unavailable (4)
OCS/WILSON 1981 .	Wilson et al. (1981)	1	H, C	unavailable (2)
DUCK IS. 1981	Colonell and Weingartner (1982)	3	H, C, D, M, S	unavailable (2)
YO191 1981	Toimil and England (1982)	3	C	unavailable (6)
OLIKTOK 1981-82	Woodward-Clyde (1983)	2	H, C, M, S	unavailable (5)
WATER FLOOD 1981 .	Mangarela et al. (1982)	3	H, C, D, M, S	unavailable (5)

Table Z-l. (continued)

Project Name/Year	Reference	Subregions Sampled	Data Types	Data Status
WATER FLOOD 1982-84*	Savoie and Wilson (1986)	3	H, C, M, S	project data base
PRE-ENDICOTT 1982	Britch et al. (1983)	3	H, C, M, S	project data base
OCS/HACHMEISTER 1982*	Hachmeister and Vinelli (1983)	5	H, C	NODC; project data base
TERN IS. 1982	Northern Technical Semites (1983)	3	C	project data base
MUKLUK 1983-84	Northern Technical Services (1985)	2	C	project data base
LISBURNE 1983-84	Beny and Colonell (1985)	3	H, C, D, M, S	project data base (except H - 1984)
ENDICOTT 1985-87”	Short et al. (1988)	2, 3	H, C, D, P, M, S	project data base
ENDICOTT 1988-90*	Morehead et al. (1990)	3	H, C, M, S	unavailable (5)
OCS/BSMCS 1986-88*	Aagaard et al. (1989)	1,2, 3,4,5	H, C, D, M, S	NODC; project database
ANWR 1988-89”	Fruge et al. (1989)	4,5	H, C, M	project data base (1988 only)

● Collected under U.S Government agency funding or regulation.
For unavailable data:
(1) Data unavailable due to proprietary restrictions or excessive cost.
(2) Investigator or institution indicated that the data are inaccessible or would require excessive effort to locate and retrieve.
(3) Investigator indicated data sent to NODC, but not found in the archive.
(4) Investigator or knowledgeable party could not be reached.
(5) No response received to request for data.
(6) Data not archived in digital form.

MIZPAC, WATERFLOOD, BSMCS) where *such* exists, or by the investigator/institution that conducted the experiment. In some cases, one experiment was broken down into two or more data sets, if the principal investigator(s) or some other major aspect of the experiment changed (e.g., ENDICOTT 1985-87, ENDICOTT 1988-89). Those experiments that were elements of the OCSEAP program were designated by the prefix "OCS". A total of 43 of the 56 data sets (77 percent) were either funded or controlled by public agencies.

Of the 56 documented data sets, only 21 were present in their entirety (or nearly so) in the NODC holdings. In one additional case (OCS/MATTHEWS 1977-81) only a small fraction of the data known to have been collected was found in the NODC data base. An additional seven data sets (sine incomplete) were acquired from other sources. Thus, 27 of 56 documented data sets were unavailable for acquisition. The reasons for the unavailability of these data sets generally fell into two categories. First, in some cases it was either impossible to locate the original investigator(s), or if located, the investigator indicated that the data set was no longer accessible. Second, many of the data sets collected by private funding sources (primarily oil companies) were unavailable due to proprietary constraints. In such cases, the funding company or companies maintains confidentiality on the data for a specified number of years (typically 10). Even when the restriction is lifted, an exorbitant cost may still be imposed for anyone wishing to purchase the data. These proprietary restrictions generally applied to studies conducted in conjunction with oil exploration activities (e.g., BEAUMOP), but not necessarily to privately funded monitoring studies associated with EIS assessments or pennit requirements for oil development activities (e.g., WATERFLOOD, ENDICOTT, LISBURNE).

Certain of the missing data sets, due to their documented extensive data coverage in space and/or tire, were deemed high priority for additional efforts at retrieval. These efforts, within the scope of the present study, met with limited success. If additional data compilation efforts are attempted in the future, it is suggested that special attention be given to the location, retrieval, and incorporation of the following high priority data sets into the available public record: OCS/MATTHEWS (1977-81); BARNES (1971-76); BEUMOP (1978-83); and ENDICOTT (1988-90).

The absence of the OCS/MATTHEWS 1977-81 data set deserves special. note. According to Matthews (1978, 1.979, 1980, 1981), more than 35 current meter deployments were carried out in the Simpson Lagoon area during this five-year period. Several of Matthews' deployments resulted in lost instruments with no data recovery. Only data from 1977 and 1978 were present in the NODC archives, and upon close impaction, even they proved to be unusable due to sampling or recording interval problems. Several of Matthews' data tapes, provided by the University of Alaska, were found to be indecipherable, even by the current meter manufacturer. The loss of Matthews' data is an unfortunate and disappointing gap in the historical data record.

3.0 DATA ANALYSIS AND INTERPRETATION

3.1 METHODS

3.1.1 Data Input/Output Management

3.1.1.1 Standard Input Format

In view of the variety of formats of obtained data sets, NODC data format was chosen as a standard input format, and each analytical program included a subroutine that served as the data input section. This subroutine accepted parameters that selected oceanographic or meteorological format and wrote header information to the computer file defined to accept computed results.

3.1.1.2 Interactive Input of Parameters

Analytical programs included a standard input query sequence. Analyses required items of information such as file names for selecting particular data records, data type, desired velocity component, whether or not to rotate into principal axis orientation, total number of data points to interpolate for fast fourier transforms (FFT's), and smoothing intervals for output plots. For ease of use of the programs even by individuals unfamiliar with the routines, the decision was made to use an interactive exchange rather than require modification of an input file for each analysis run*

3.1.1.3 Real-time on–screen Plot Display

A real-time on-screen plot display feature allowed the analyst to display output plots on the computer screen upon completion of computer runs. This feature played an extremely 'important role in previewing the results of the large number of analytical runs required by the program. 'Ibis preview allowed the option of re-specifying input parameters to improve the information content of plots and computed results before producing hardcopy output. It also improved data analysis efficiency by providing immediate results that could be used to choose subsequent avenues of analysis of a given suite of data.

3.1.1.4 Production of Output Disk Files

Output sections of all programs wrote both computed and graphical outputs to user-specified disk files. The feature provided results for record in an easily readable format and files of plot instructions that could be used to make multiple original copies of graphs without rerunning analytical programs. Plot files were of two types, one of instructi' ons for a Hewlett-Packard model 7475A pen plotter and the other of instructions for an Imagen laser printer. Output disk files were intended as a means of maintaining permanent records of results of all the various computer runs.

3.1.2 Data Manipulation

3.1.2.1 Conversion to NODC Format

Many of the data sets obtained were in non-standard formats and required conversion into NODC format before analysis. Programs for each different format conversion were written in C and produced output files of header information and data in either oceanographic or meteorological NODC format.

3.1.2.2 Checking for Missing Data

Missing data in original data sets were entered either as blanks or as entries of -999* depending on the source. Format conversion routines scanned for either type of entry and wrote -999 as the entry for any missing data. The data records that were chosen for analysis were then edited to search out any -999 entries. Very few blocks of missing data were found. Data records were truncated if a block fell near either end, and in one case, missing data from one data record (1985 Resolution Island MET data) were replaced by two blocks of comparable data (Deadhorse MET data) slightly longer than 24 hours.

3.1.2.3 Subsampling

A sampling rate of one hour was selected as standard for all data used by the program. Some of the data sets obtained had sampling intervals other than one hour. Those data sets were subsampled to yield time series with one-hour sampling interval at the top of each hour.

3.1.2.4 Truncating

Data sets contained time series of various lengths. Time series were truncated, either beginning or end, in order to achieve start times and record lengths matching other records with With correlations or other joint calculations were made. Calculations made with individual records generally used the entire record length as long as the record corresponded approximately with typical deployments in a given data set. Where specific calculations were desired for a given time series for an interval concurrent with another data record, only the corresponding segment was used, regardless of record length.

3.1.3 Selection of Data Sets for Analysis

3.1.3.1 Oceanographic Data

Current meter records selected for analysis came from the years 1982 and 1984 through 1988. The criteria considered when selecting data sets for analysis included length of record, geographic location, concurrence with other data records on the same mooring, and existence of records from the same location in successive years. Only current meter records from the open water season (mid/late-July to mid-September) were available and were thus limited to a maximum of about eight weeks. Many were shorter due to instrument malfunction or damage. Preference was given to longer records for analysis. In view of the shallow depths (l-2 m) inside the barrier islands, the strong constraint imposed on current direction by lateral barriers on two sides, and the sheltering effect of barrier islands against offshore motions, current records from outside the barrier islands were given preference. The potential for investigating the variation with depth of current response to wind forcing led, whenever possible, to the choice of vertically separated current records from the same mooring. Current records separated either in the alongshore or offshore direction were chosen in order to investigate the presence of propagating signals not directly attributable to local wind forcing. In summary, current records selected for analysis were chosen on the basis of potential for investigating current-wind relationships and illuminating other dynamical processes that might contribute to current variability in the nearshore area.

3.1.3.2 Meteorological Data

Meteorological data sets were chosen on the basis of proximity to (and concurrence with) the selected current records. For current records from the Prudhoe Bay area, the first choice for wind-current analyses was Resolution Island, slightly northeast of Prudhoe Bay. Winds from Deadhorse and Gull Island were also used. For the analysis of 1988 current meter data from Camden Bay, wind data were from a temporary meteorological recording shore station south of Camden Bay.

3.1.4 Analytical Tools

3.1.4.1 Autocorrelation

Lagged autocorrelations were calculated for most of the data records. One use of autocorrelations was to estimate the approximate time interval necessary for current motions to be independent. A second was to supplement the results of autospectral calculations by means of lending visual. confirmation for spectral peaks, but perhaps the most important was simply to provide a simple descriptive representation of the frequency content of a given current record.

The autocorrelation routine comes from Bendat and PierSol (1971, chapter 9). Ninety-five percent confidence limits were calculated using the Fischer z-transform (Otnes and Enochson, 1978) and were plotted as dashed lines on the output graphs.

3.1.4.2 Cross Correlation

Lagged cross correlations ware calculated between winds and currents and between selected current record pairs. The basic routine is analogous to that for autocorrelation, with the exception that both negative and positive lags were used.

Cross correlations were used to investigate the lead/lag relation between pairs of data records, particularly winds and currents. In addition, cross correlations provided evidence of periodicities at which winds and currents or current record pairs were potentially related.

3.1.4.3 Autospectra

Autospectra are the frequency domain counterparts of autocorrelations and yield an estimate of the distribution of variance as a function of frequency. Autospectra were calculated for wind and currents in order to identify frequencies at which energy associated with fluctuations was concentrated, thus to aid in isolating potential dynamic mechanisms.

Spectra were estimated by linearly interpolating data series to an integral multiple power of 2, tapering by applying a half-cosine bell to the first and last 10 percent of the data series, calculating the Fourier coefficients using an FFT routine, and then manipulating the coefficients to produce spectral estimates. The artificial production of high frequency information by interpolation was inconsequential because frequencies of signals of interest were tidal and lower and because there was very little energy to begin with in signals with time scales of a few hours or less.

Spectral plots were smoothed using a boxcar window whose width varied logarithmically with frequency (Irish et al., 1976). Thus, at low frequencies, very few successive spectral estimates were averaged together, and the number increased with increasing frequency.

3.1.4.4 coherence and Phase

Coherence and phase calculations are the frequency domain counterpart of cross correlations. The coherence calculations represent the joint distribution of energy of two data series as a function of frequency, and the phase calculations quantify the lead/lag relation of two data series also as a function of frequency. While cross correlation gives an indication of the overall relation of two time series, coherence and phase calculations isolate particular frequencies at which the relatedness is strongest.

Coherence and phase *routines* follow a method presented in Jenkins and Watts, 1968, chapter 9. Co- and quad-spectra were calculated from Fourier coeff icients (computed as for autospectra) and then manipulated to obtain estimates of coherence and phase. These were smoothed using a fixed-length linear boxcar window, the 95 percent confidence limit for coherence determined, and finally, the results plotted against a linear frequency scale.

3.1.4.5 Rotary Spectra

Rotary spectra were calculated in a limited number of cases. As the name implies, this type of analysis investigates the rotational nature of a given vector time series, yielding the energy in clockwise and counterclockwise motions as a function of f=zl==Y. This technique is useful in examining possible dynamic mechanisms as sources of observed variability. For instance inertial motions in the northern hemisphere would show up as a concentration of energy in clockwise rotations as opposed to counterclockwise rotations.

The routine is based upon the method of Gonella (1972) and Mooers (1973). The foundation for calculating rotary spectral densities rested upon manipulating the Fourier coefficients for the U and V velocity components of a given record. The rotary spectral densities were then smoothed using the same techniques as for autospectra and plotted as solid and dashed lines against frequency on a single graph.

3.1.4.6 Complex Linear Regression

Complex linear regression is the regression of one vector time series onto another. It is used to recover the fraction of variance of one time series (dependent variable) that is accountable by a linear relation to another (independent variable). The technique also produces a scale factor relating the speeds and an angle relating the directions of the two vector time series (the indraft angle). Complex regression was one of the primary tools used to examine the relation between wind and currents and between pairs occurrent and wind records. The program produced a file of computed results, but no graphical output.

3.1.4.7 Rotation into Principal Axis Orientation

All *analytical* program included a query option of rotating input time series into principal axis orientation before performing computations. Rotation into principal axis orientation means rotating the coordinate system so that one axis lies in the direction of maximum current variability, and the other lies perpendicular to it. The convention used throughout was that the velocity component he the direction of the principal axis was termed the U component, and that perpendicular was the V component. This option was exercised as a matter of consistency, since the proximity to the coastline and shallow depths generally constrained current directions. Thus, comparisons between u components of time series had a consistent meaning regardless of the actual geographical orientation of the coordinate system.

3.2 SUMMARY AND ASSESSMENT OF ANALYZED m

3.2.1 1982 Data

Data records from four current meters deployed as part of a baseline study near the mouth of the Sagavanirktok River (Britch et al., 1983) were chosen for analysis (Figure 3-1, Table 3-1). For the deployment interval, meteorological data used were from a recording station on Resolution Island, an artificial drilling island within 3 to 11 km of the moorings (Figure 3-1, Table 3-1).

One problem that immediately became apparent from cross correlations between wind and current records and between current record pairs was that start times listed for moorings L1 and L3 were incorrect and offset by slightly more than two days. Cross correlations between L4, L5 and the wind indicated apparently correct listed start times for those two current time series. Under the assumption that L1 and L5 were in phase because of their close proximity, as

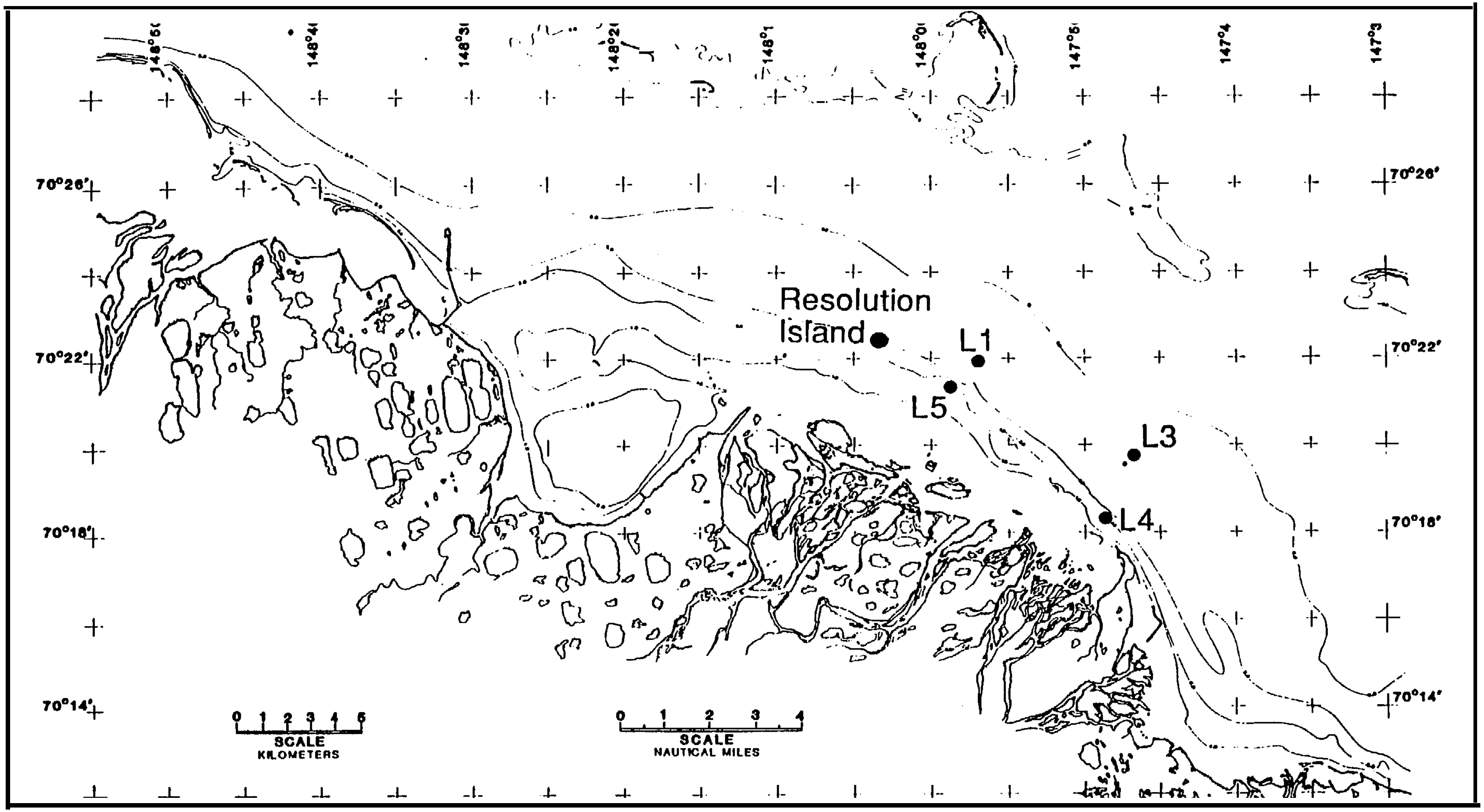


Figure 3-1. Location of 1982 current meter and meteorological data records selected for analysis.

Table 3.1. Details of current records and meteorological data, 1982

File name is the name of the computer disk file for the data and identifies each respective data record on output plots and computed results files.

I. Il.	File Name	Current Record Begin		Current Record End		Mooring Location Latitude (N)	Mooring Location Longitude (W)	Depth (m) sensor/bottom
L1	L1.C82	07/29	1100	09/13	0600	70%1. 9'	147056.7'	3.0/5.0
L3	L3.C82	07/31	1900	09/13	0600	70°19.7'	147°47.01	3.0/5.0
L4	L4.C82	07/31	1200	09/15	0800	70°18.3'	147°48.81	1.0/2.0
L5	L5.C82	07/30	1700	09/15	0800	70°21.41	147°59.0'	1.0/2.0
Resolution Is.								
Met Data	RI.W82	06/21	1800	09/15	1400	70°22.31	148°03.11	

were L3 and L4, start times for L1 and L3 were adjusted by 53 and 57 hours, respectively, based upon the results of cross correlation calculations. This adjustment approximately aligned the data points of the four time series and compensated for the incorrect times associated with the acquired L1 and L3 data. Even so, the potential errors in adjustments to start times are 1-3 hours, With corresponds to typically observed phase lags between winds and currents analyzed for this project. Thus, no strong conclusions were attempted on the basis of cross-calculations between L1, L3, and the wind.

3.2.2 1984 Data

Three current inter records from 1984 were chosen for analysis (Figure 3-2, Table 3-2). They were obtained during a monitoring program in the Prudhoe Bay area (Berry and Colonell, 1985) . These three current records were from deployments that were among the deepest in the nearshore area and provided simultaneous measurements separated in both alongshore (132 and L36) and cross-isobath (132 and L34) directions. There were no gaps in the records and no apparent discrepancies in start times. However, the subsequent data report (Berry and Colonell, 1985) indicated that all three moorings had been struck and dragged by ice. Simple calculations showed that the vector-averaged mooring velocities were 0.5 an/s for L34 and 0.2 cm/s for 132 and 136. These are comparable to the observed vector-averaged velocities, and therefore, relative velocities induced by mooring movements bias investigations of means for these records. On the other hand, the contribution from mooring movement will not greatly affect spectral results, since #e means are removed before commencing calculations. In view of the spatial distribution and of the validity of spectral calculations in spite of mooring translations during the deployment intervals, these current records were included in the analysis.

Meteorological observations from Deadhorse Airport were used in the analysis. Meteorological data were also available from Gull Island, located in the north part of Prudhoe Bay. Complex regression calculations between the two data sets Heated that wind directions at the two locations differed by only seven degrees, and that Gull Island wind speeds averaged about 70 percent of Deadhorse wind speeds. Gull Island winds led by one to - hours. Deadhorse winds were selected on the basis of longer record overlap with the current records and continuous year-to-year coverage, should current predictions for the general area covered by the three mooring locations mentioned above be attempted for other years.

3.2.3 1985 Data

Numerous current meters were deployed *in the* Prudhoe Bay area during the 1985 open-water season as part of the Endicott Environmental Monitoring Program (Hachmeister et al., 1987). Many yielded short data records, some were deployed in water 2 m or less deep, and some were located inshore of a manmade gravel causeway stretching several kilometers alongshore and connected to shore by another causeway with several breaches in it. Three current records were included in the analysis (Figure 3-3, Table 3-3). Two of the current records (ED2 upper and lower) provided an opportunity to study vertical

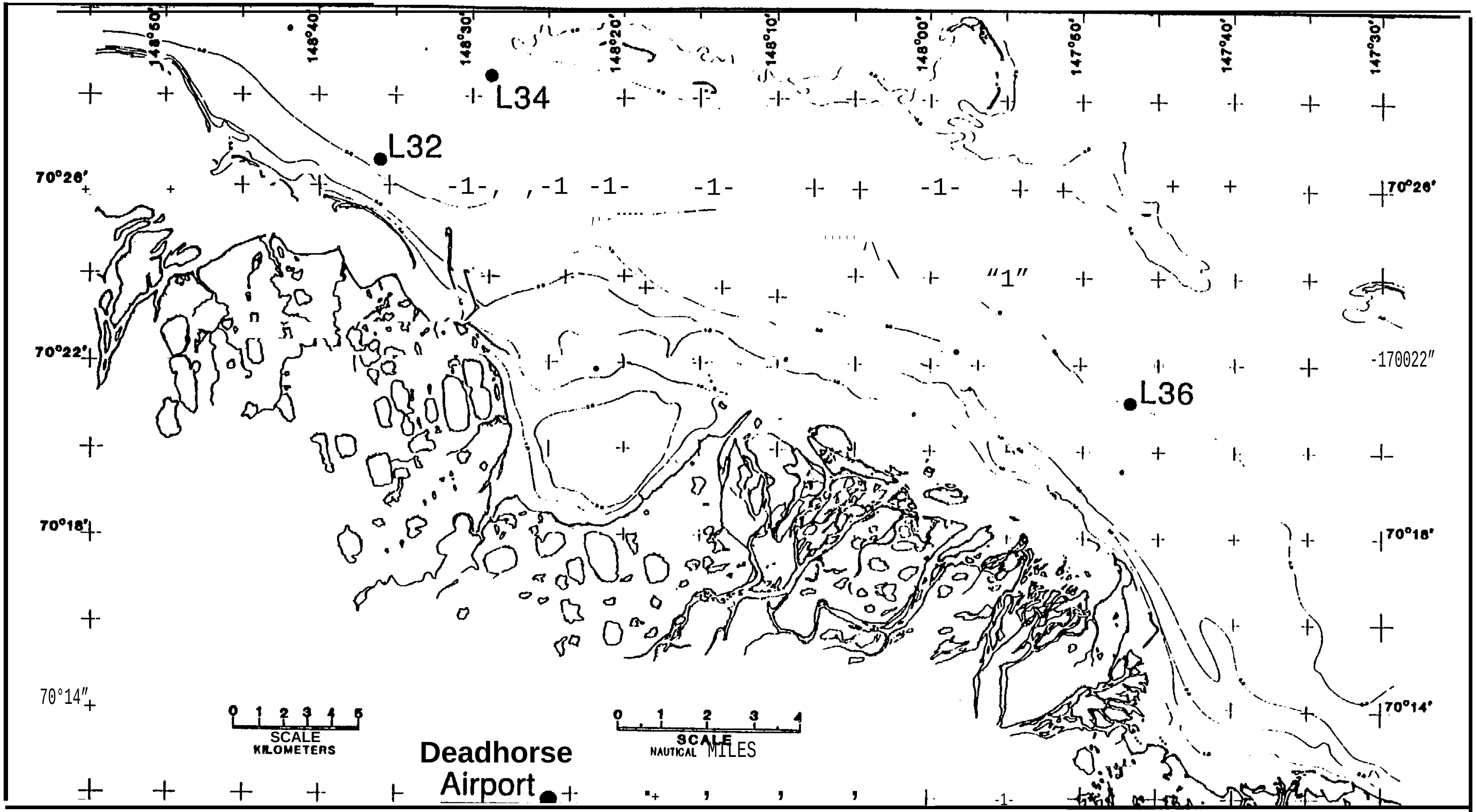


Figure 3-2. **Location** of 1984 current meter and meteorological data records selected for analysis.

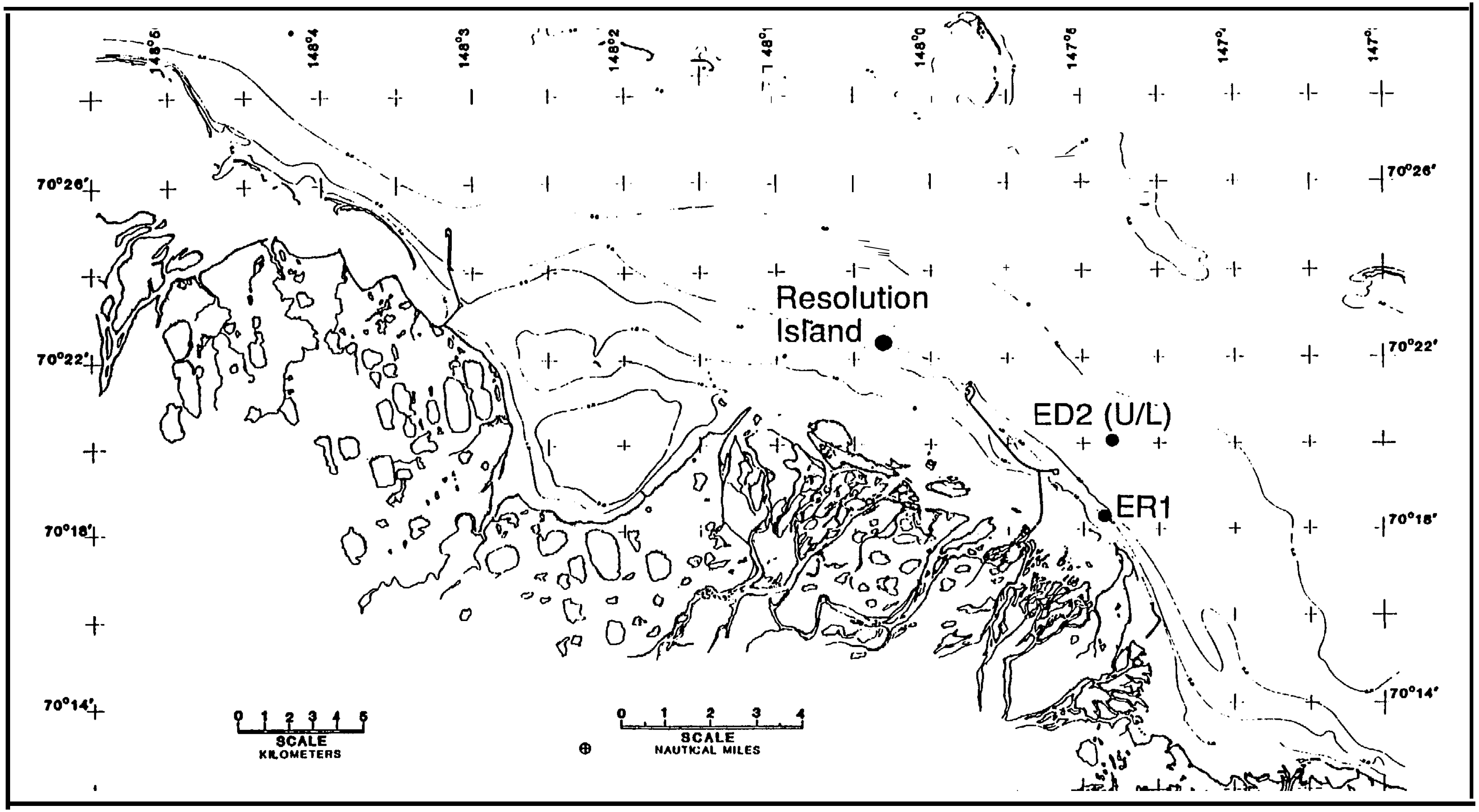


Figure 3-3. Location of 1985 current meter and meteorological data records selected for analysis.

Table 3.2 Details of current records and meteorological data, 1984

File name is the name of the computer disk file for the data end identifies each respective data record on output plats and computed results files.

I.D.	File Name	Current Record Begin	End	Mooring Location Latitude (N)	Longitude (W)	Depth (m) sensor/bottom
132	L32 . C84					
or	132 .s84	08/06 0600	09/17 2200	70°26.3'	148°36.1'	4.6/6.4
L34	L34.C84					
or	L34 . S84	08/05 0500	08/29 0800	70°28.3'	148°28.5'	7.3/9.1
L36	L36.C84					
or	L36.S84	08/06 0200	09/12 0500	70°21.4'	147°46.6'	4.6/6.4
Deadhorse Airport						
Met Data	DH.W84	06/01 0100	09/30 2400	70°11.92'	148°26.47'	
Gull Island						
Met Data	GI.W84	06/22 0100	09/15 1500	70°22.0'	148°43.9'	

Table 3-3. Details of current records and meteorological data, 1985

File name is the name of the computer disk file for the data and identifies each respective data record on output plats and computed results files.

I.D.	File Name	Current Record BeYin	End	Mooring Location Latitude (N)	Longitude (W)	Depth (m) sensor/bottom
ER1	ER1H.C85	07/25 1159	09/13 1059	70°18.3'	147°48.8'	1.0/2.0
or	ER1.C85					
ED2upper	ED2UH.C85	08/08 3.205	08/25 1705	70°20.5S	147°48.3a	2.0/5.0
or	ED2U.C85					
ED2lower	ED2LH.C85	08/08 1158	09/13 1158	70%0.5'	147°48.3'	4.0/5.0
or	ED2L.C85					
Resolution Is.						
Met Data	RMETL.W85	07/16 0100	09/19 1200	70°22.3'	148°03.11	
or	RI.W85					

relationship between currents at the same location and, in addition, were obtained seaward of the Shielding effect of the artificial barrier. Record lengths were 18 and 36 days, respectively. While current record ER1 was measured at a depth of 1.0 meter, it was included because its 50-day retard length provided the best opportunity of detecting long-period current f luctuations. None of these current records had any apparent errors.

Resolution Island meteorological observations supplied the wind data for the 1985 analysis. These data contained two gaps, 08/03 1800 to 08/05 2000-09/08 1100 to 09/09 1400. The relation between Resolution Island and Deadhorse Airport observations were deemed sufficiently close that Deadhorse Airport observations were substituted directly into the two gaps in the Resolution Island data. Resolution Island data were favored over Deadhorse data because of closer proximity to the Current meter moorings.

3.2.4 1986 Data

Several current records were chosen from the 1986 Endicott Monitoring Program (Short et al., 1987) nearshore data set obtained in Stefansson Sound near Prudhoe Bay (Figure 3-4, Table 3-4). These current records were chosen because of their long duration and distribution both in shallow water and in nearshore locations off shore of the gravel causeway. All the current records were complete and showed no apparent deficiencies. Data collection was terminated by ice encroachment just prior to deployment of current meters farther offshore that initiated the Beaufort Sea Mesoscale Circulation Study (Aagaard et al., 1989) . Nearshore data were not available for comparison with offshore data in 1986.

As in 1985, meteorological data were available from a recording station on Resolution Island. These data supplied wind information used in the 1986 analysis.

3.2.5 1987 Data

A third-year continuation of the Endicott monitoring program in Stefansson Sound near Prudhoe Bay (Short et al., 1988) supplied nearshore current records for analysis . Current records came from three mooring locations seaward of the alongshore barrier lying off the mouth of the Sagavanirktok River (Figure 3-5, Table 3-5). These records provided the opportunity to investigate the relation of currents both vertically at a single location (the same as in 1985) and horizontally alongshore at separations of approximately 6 and 12 km.

one current retold, ED1, contained a gap from 08/17 0600 to 08/17 1800, the interval for recovery of one current meter and deployment of another in the same location. In view of the gap length relative to the total record length of 48 days, the gap was bridged by linear interpolation, the assumption being that calculated results would differ little from those obtained if a more sophisticated method were used to bridge the gap. Indeed, calculations made with the gap filled with zeroes were nearly identical with those made after bridging by linear interpolation.

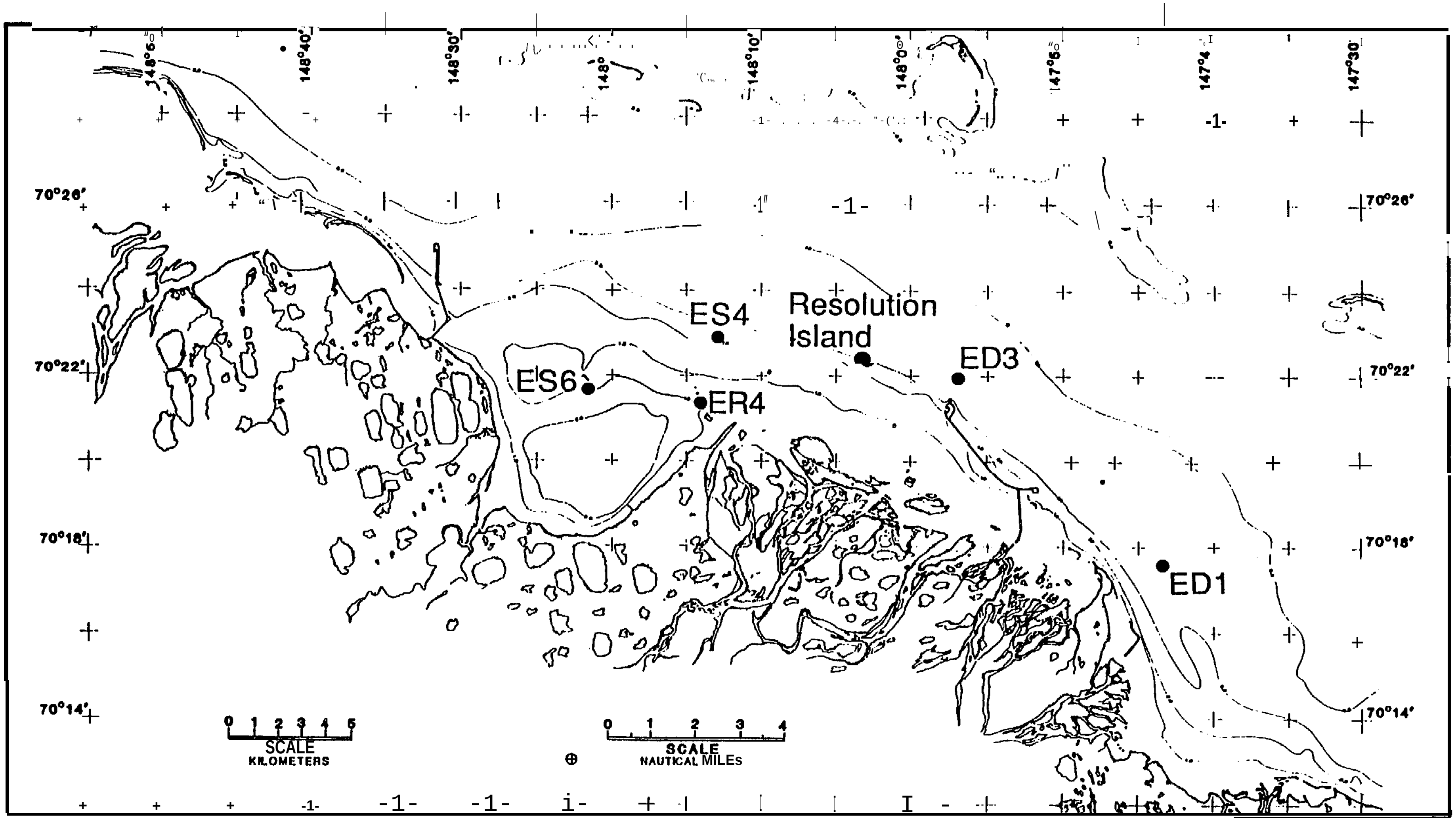


Figure 3-4. Location of 1986 current meter and meteorological data records selected for analysis.

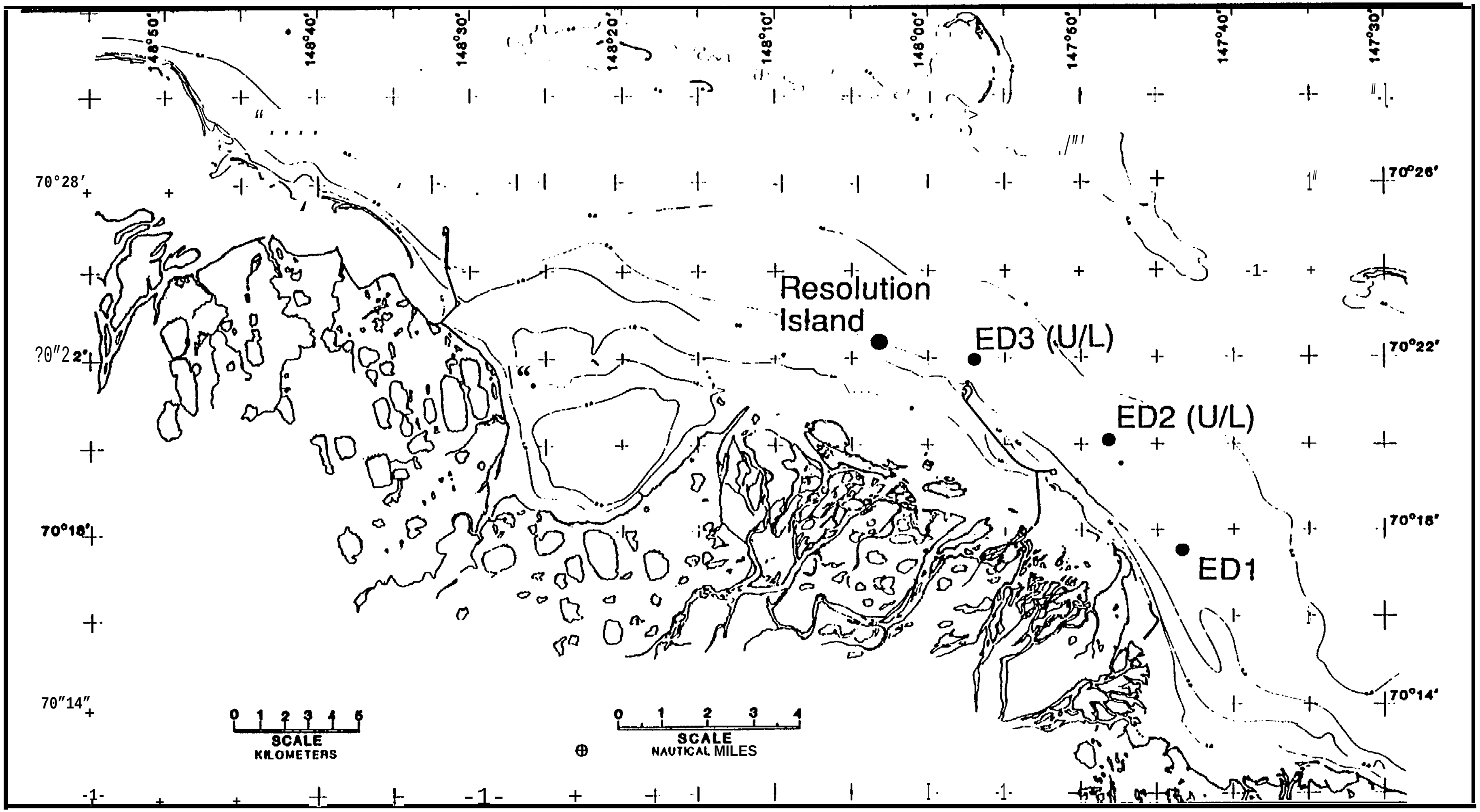


Figure 3-5. **Location of 1987 current meter and meteorological data records selected for analysis.**

Table 3-4. Details of current records and meteorological data, 1986

File name is the name of the computer disk file for the data and identifies each respective data record on output plots and computed results files.

		Current Record		Mooring Location		Depth (m)
I.D.	File Name	Begin	End	Latitude (N)	Longitude (W)	sensor/bottom
ED1	ED1. C86	07/27 1200	08/23 0800	70°17.6'	147°43.01	2.7/4.0
ED3upper	ED3 .C86	07/27 3.200	09/10 1100	70°21.9'	147056.7 '	2.7/5.0
ER4	ER4.C86	07/29 1800	09/11 3.200	70°21.1'	148°14.41	0.9/1.0
ES4	ES4.C86	07/29 1800	09/11 1300	70°22.9'	148°13.0'	1.5/2.0
ES6	ES6.C86	07/29 1800	09/04 1000	70°21.7'	148°22.0'	0.6/1.0
Resolution Is. Met Data	RI.W86	05/31 1300	09/30 1600	70°22.31	148°03.11	

Table 3-5. Details of current records and meteorological data, 1987

File name is the name of the computer disk file for the data and identifies each respective data record on output plots and computed results files.

		Current Record		Mooring Location		Depth (m)
I.D.	File Name	Begin	End	Latitude (N)	Longitude (W)	sensor/bottom
ED1	ED1.C87	07/25 0000	09/11 0000	70°17.6'	147°43.0'	3.1/4.0
ED2upper	ED2U.C87	07/24 1100	09/11 1000	70°20.5'	147°48.3'	2.4/4.2
ED2lower	ED2L.C87	08/12 2100	09/11 1100	70°20.5'	147°48.3'	4.0/4.2
ED3upper	ED3U.C87	08/25 1700	09/11 0700	70°21.9'	147°56.7'	3.0/5.0
MB2B-1		04/05/87	04/04/88	70°55.1'	146°45.8'	72/185
MB4B-1		04/03/87	03/30/88	70°52.6'	146°57.3'	52/60
Resolution Is. Met Data	RI.W87	05/29 1800	09/30 1200	70°22.31	148°03.1*	

These current records overlapped current records obtained further offshore as part of the BSMCS. They were used subsequently to investigate the relation between nearshore wind and currents and offshore currents about 70 to 80 km north-northeast of the Stefansson Sound sites.

A recording station that was installed on Resolution Island provided wind data used in 1987 calculations. The wind data contained no gaps or deficiencies and totally bracketed the current meter deployment intervals.

3.2.6 1988 Data

Current meter data available to the program from 1988 were limited. A single current record, from a monitoring project in the area just offshore of the Arctic National Wildlife Refuge (ANWR), was chosen (Figure 3-6, Table 3-6). While other current meters were deployed, they were very near shore or in protected areas, and it was felt that calculated results would be of very limited use, if any. current meters deployed as part of the Beaufort sea Mesoscale Circulation Study were recovered in March and April 1988, so there were no overlapping nearshore and offshore current records for analysis.

A temporary MET station installed on the spit at Simpson's Cove in Camden Bay was the source of meteorological data for the ANWR current meter data comparison. The length of the meteorological data record was slightly shorter than the current meter record, but contained no gaps or other problematic features.

3.2.7 1989 Data

Data from 1989 chosen for analysis were two current meter records from mooring location CB6, the same as the 1988 ANWR data, and a nearshore current record CB2 (Table 3-7). Locations are indicated on Figure 3-6. Choosing the 1989 CB6 current records allowed comparison with 1988 data from the same location and examination of currents separated vertically in the water column. There were no current meters deployed offshore simultaneously with the 1989 ANWR deployments, so no nearshore/off shore comparison was possible.

As in 1988, a temporary MET station installed on the spit at Simpson's Cove in Camden Bay provided meteorological data for the 1989 deployments in Camden Bay.

3.3 RESULTS AND DISCUSSION

3.3.1 Wind and Nearshore Currents

3.3.1.1 wind-explained current Variance

The percentage of current friability explained by the wind varied both spatially and temporally, and showed a distinct depth dependence (Table 3-8). Generally, the wind accounted for approximately 40-50 percent of - - - of nearshore currents at current meter depths of 3 m or less in water that was less than about 6 m. In contrast, wind explained only about 1-1o percent of the variance at depths greater than 3 m (Table 3-8, 1984 entries) where bottom

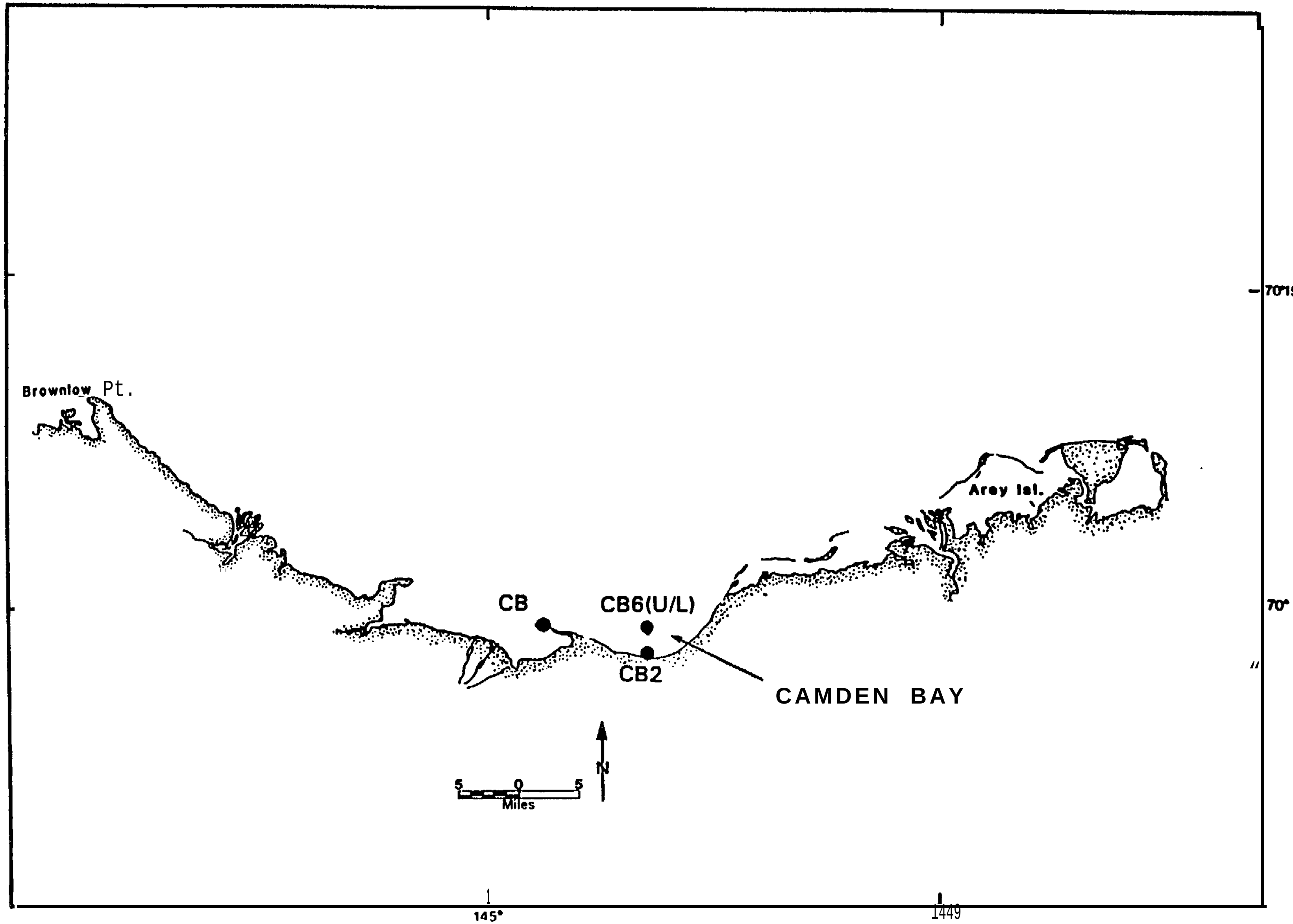


Figure 3-6. Location of 1988 and 1989 current meter and meteorological data records selected for analysis.

Table 3-6. Details of current records and meteorological data, 1988

File name is the name of the computer disk file for the data and identifies each respective data record on output plots and computed results files.

I.D.	File Name	Current Record Begin	Current Record End	Mooring Location Latitude (N)	Mooring Location Longitude (W)	Depth (m) sensor/bottom
CB6lower	CL.C88 or CB6L.C88	08/06 2200	09/12 1700	69°59 '	144°431	6.6/7.6
Camden Bay Met Data	CB.W88	08/05/1300	08/28 1300	69°59 '	144°52 '	
Pokok Bay Met Data	PK.W88	08/10 0000	09/13 1500	69°59 '	142°331	

Table 3-7. Details of current records and meteorological data, 1989

File name is the name of the computer disk file for the data and identifies each respective data record on output plots and computed results files.

I.D.	File Name	Current Record Begin	Current Record End	Mooring Location Latitutde (N)	Mooring Location Longitude (W)	Depth (m) sensor/bottom
CB2	CB2. C89	08/03 0000	09/09 1900	69°581	144°431	2/3
CB6upper	CB6U.C89	08/03 0000	09/10 3.200	69°59 '	144°431	5/8
CB6lower	CB6L.C89	08/03 0000	09/10 0500	69°59 '	144°43 '	7/8
Camden Bay Met Data	CB.W89	08/03 1.200	09/10 1900	69°59 '	144°521	

Table 3-8. **Summary of regression and U-component correlation calculations between wind and currents.**

Year Data File Name	Current variance Explained by Wind (%)	Cross 1/ Correlation Maximum (lag/W)	Factor Relating correlated Wind and Current Speeds	Indraft Angle of current Relative to Wind L or R	Depth (m) sensor/bottom
3.989					
CB6U.C89	28	**0.65(1)**	.018	**73°R**	3/8
CB6L. C89	3.5	**0.48(5)**	.009	**18°R**	7/8
CB2.C89	10	**0.41(4)**	.006	51%	2/3
1988					
CB6L.C88	19	0.56 (2)	.007	48%	6.6/7.6
1987					
ED1. C87	35	0.76(3)	.013	**53°R**	3.1/4.0
ED2U.C87 2/	55	**0.91(2)**	.027	**43°R**	2.4/4.2
ED2L. C87	33	**NC** 4/	.014	**22°R**	4.0/4.2
ED2U.C87 3/	45	NC	.026	**45°R**	2.4/4.2
ED3U.C87	47	NC	.025	40%	3.0/5.0
MB4B-1.C87		0.69(8)			52/60
1986					
ED1. C86	39	NC	.013	**48°R**	2.7/4.0
ED3 . C86	39	NC	.021	**33°R**	2.7/5.0
ER4 . C86	53	NC	.020	46%	0.9/1.0
ES4.C86	27	0.82(3)	.008	**4°R**	1.5/2.1
ES6 . C86	45	NC	.011	31'%	0.6/1.0
1985					
ER1.C85	32	0.49(1)	.009	**63°R**	1.0/2.0
ED2U.C85	41	0.73(3)	.009	46%	2.0/5.0
ED2L.C85	3	0.38(6)	.002	14%	4.0/5.0
1984					
L32.C84	3	NC	.001	10%	4.6/6.4
134. C84	0	**NC**	.0001	**90°R**	7.3/9.1
L36.C84	9	0.43(6)	.007	**13°R**	4.6/6.4
1982					
L1.C82	50	0.82(2) 5/	.018	**82°R**	3.0/5.0
L3. C82	52	0.83(-2) 5/	.023	**59°R**	3.0/5.0
L4.C82	43	0.81(1)	.015	**83°R**	1.0/2.0
L5.C82	49	0.77(3)	.014	**23°R**	1.0/2.0

1/ **Wind** leads for **positive** lags.
2/ Record **starts at** 0000 on 25 July 1987.
3/ **Record starts at** 2100 on 12 **August** 1987.
4/ N C = Nut **computed.**
5/ **Exact lag** is dubious because of **start-time errors.**

depths were greater than about 6 m. However, in two cases in 1987, wind explained 33 percent and 35 percent of variance of deeper currents at mooring locations ED1 and ED2, respectively. Note that the same is not true for 1985, ED2, when wind explained only 3 percent of the variance of the deeper currents. These comparisons, along with comparisons of the scale factors relating winds and deeper currents (Table 3-8) in 1985 and 1987 indicate a notable difference in wind-forcing of the deeper currents. The reason for the difference in this example is that stratified conditions persisted throughout the 1985 open water season, while well-mixed conditions characterized the majority of the 1987 open water season (Short et al., 1989). Stratification presented a buoyancy barrier that inhibited vertical transfer of momentum from the surface layer downward. The differences in the degrees of mixing - largely due to wind direction and persistence, affecting hydrographi"tax'ditim~ei- onshoreor off shore Ekman drift.

Wind accounted for a comparable fraction of current variance at a depth of approximately 7 m at mooring location CB6 in Camden Bay in 1988 (19 percent) and 1989 (15 Percent). During the 1989 deployment, wind accounted for 28 percent of the current variance at a depth of about 3 m, which is consistent with increasing fraction of wind-explained variance with increasing distance above the bottom. Vector-average wind speed and direction were similar during those two respective deployment intervals.

While the wind-explained current variance near the bottom at location CB6 in 1988 and 1989 is comparable, one striking difference is that the vector-average current direction was eastward in 1988, roughly in opposition to the wind, but north-northwestward in 1989, which may reflect geographic steering and westward wind component. In 1989, near-surface vector-average currents at location CB6 were east-southeastward, roughly opposite the near-bottom currents and also somewhat in opposition to winds. Vector-average currents at CB2 in 1989 were also eastward along the coastline, confirming a component of circulation in Camden Bay in opposition to direct wind-stress forcing. Fluctuations in wind affected fluctuations in currents similarly in both years, but there apparently were other influences such as recirculation in Camden Bay or presence of local or large-scale pressure gradients that were different between the two years.

The retarding action of bottom friction will also influence deeper currents. However, bottom friction is a passive influence that depends on current speed, which in turn is related to external forcing. The implication is that annual variability of meteorological conditions, which subsequently affect hydrographic conditions, exerts a primary influence on the degree to which wind drives deeper currents.

3.3.1.2 Correlation Analysis

Wind consistently led nearshore currents by 1-3 hours (Table 3-8). Cross correlations between wind and current major axis velocity components in the principal axis coordinate system (henceforth termed U components) ranged from 0.38 to 0.91, averaging 0.69. cross correlation functions decayed to zero within a lagged interval of about 40 to 60 hours (Figure 3-7 is typical). The maximum cross correlation between minor axis velocity components (henceforth

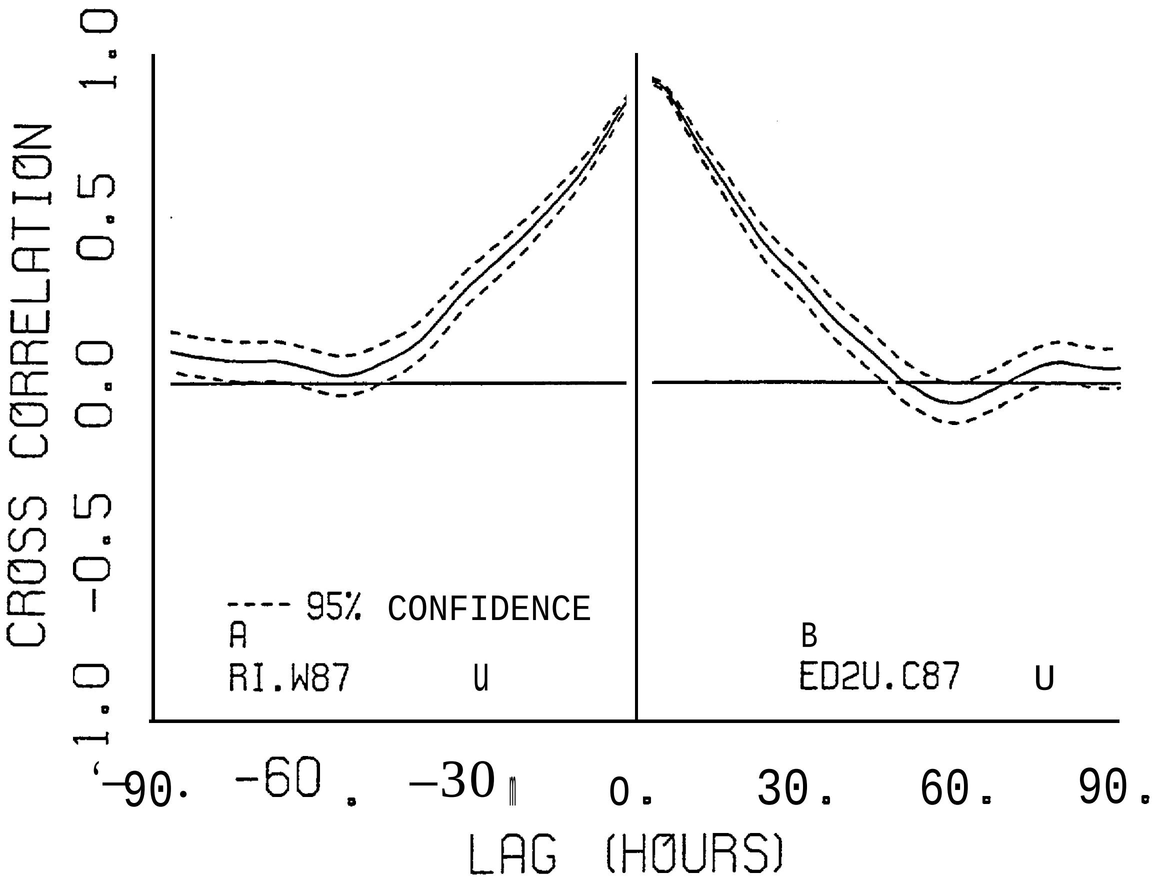


Figure 3-7. **Cross correlation between U-components of Resolution island wind andED2 upper currents, 1987. Wind leads for positive lags.**

termed V components) of wind and currents was typically between -0.4 and zero, and decayed to zero within a lag of about 10 hours (Figure 3-8). The negative correlation between wind and V components of currents indicates that the relation may be secondary within several kilometers of the coast. -- and phase calculations between wind and ED2 upper, 1987 confirm the intuitive expectation that the strongest relation is at low frequencies and that the wind and near surface currents are nearly in phase (Figure 3-9).

3.3.2 Vertical Relation between Currents

Analysis of current records from mooring location ED2, 1985 and 1987 shows interannual differences in the relation between currents measured at two depths. In 1985, wind accounted for 41 percent and 3 percent of the current variance at depths of 2 m and 4 m, respectively (Table 3-8). In 1987, however, wind accounted for 55 percent and 33 percent of the current variance at 2.4 m and 4 m, respectively (Table 3-8).

While there is a lower percentage of the current variance explained by the wind at the lower depths in both years, it is especially apparent in 1985. One significant difference is that in 1985, meteorological patterns were such that well-mixed conditions in the water column were never consistently established over the open-water season, while 1987 was a year in which the water column was either weakly stratified or well-mixed for much of the open water season (Short, et al., 1989). The direct consequence is that in 1985, stratification tended to weaken the coupling between the surface layer and the deeper part of the water column, weakening the influence of direct wind action on deeper currents. The absence of a buoyancy barrier to vertical momentum transport in 1987 led to greater wind influence on deeper currents compared to the more stratified case observed in 1985. The difference in the scale factor relating wind and currents speeds at depth in 1985 and 1987 reflects the increased coupling of wind effects to deeper currents in 1987.

Maximum U-component cross correlation coefficients between the upper and lower currents at ED2 were also different in 1985 and 1987 (Figures 3-10 and 3-11). The maximum of 0.64 in 1985 relative to 0.91 in 1987 indicates a stronger coupling of the upper and lower layers of the water column in 1987, as do the lags of 1 to 2 hours in 1985 versus 0 to 1 hour in 1987 for maximum correlation.

The V-component cross Correlation between upper and lower currents was distinctly influenced by tidal signals (cf. Figure 3-12). While the tidal signal is obvious, the cross correlation is only marginally different from zero at the 95 percent confidence limit. There is only weak evidence of longs-term correlation, shown by the broad positive peak at lag of about -45 hours and negative peak at lag of +45 hours (Figure 3-12). Coherence and phase calculations for the V-components of upper and lower current records from ED2 in 1985 (Figure 3-13) confirm the correlation at semi-diurnal tidal frequencies (0.08 cph) but show no indication of significant relation at lower frequencies. Analogous calculations for 1.987 yield coherence and phase plots (Figure 3-14) surprisingly similar to those for 1985, implying that variance along the minor axis is relatively independent of stratification and wind patterns.

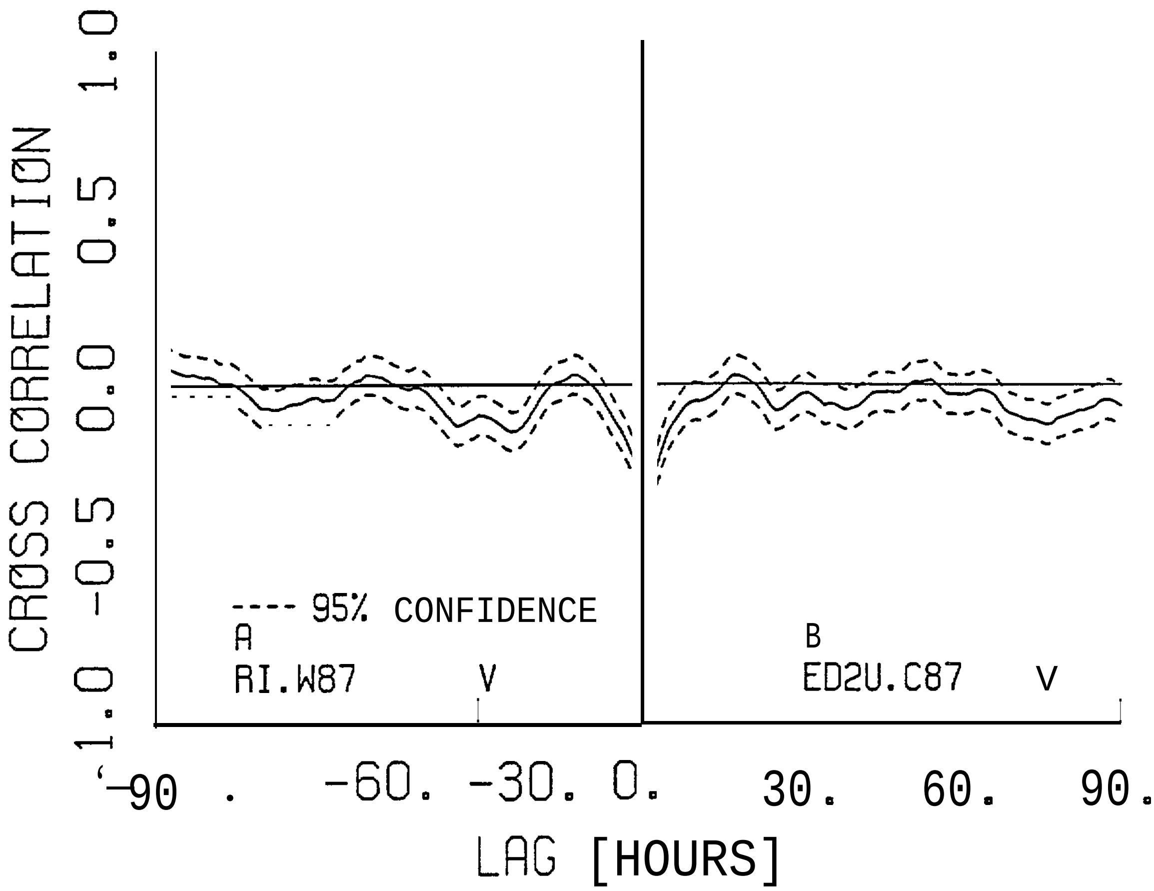


Figure *3-8.* **Cross** correlation between V-components of Resolution Island **wind and ED2** upper currents, 1987. **Wind** leads **for positive lags.**

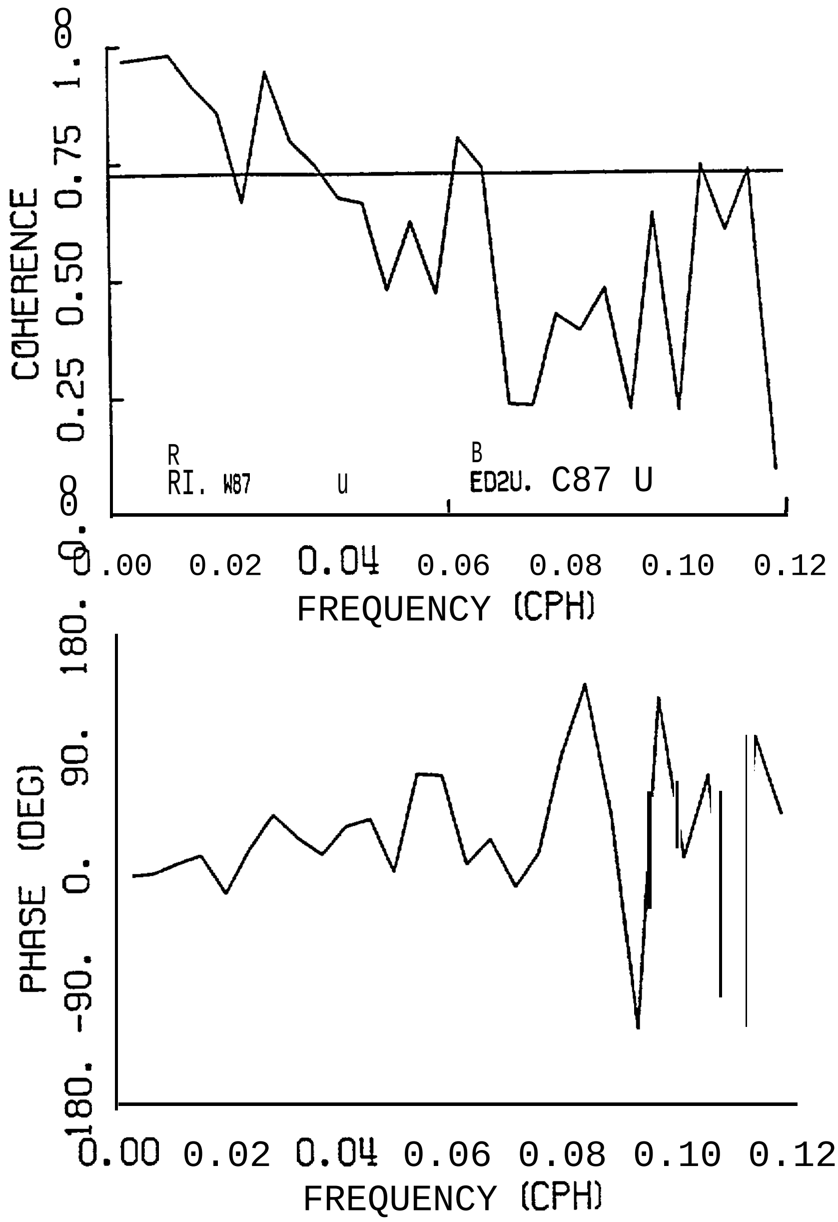


Figure 3-9. Coherence and phase between U-components of Resolution Island wind and ED2 upper currents, 1987. Positive phase indicates wind leads currents.

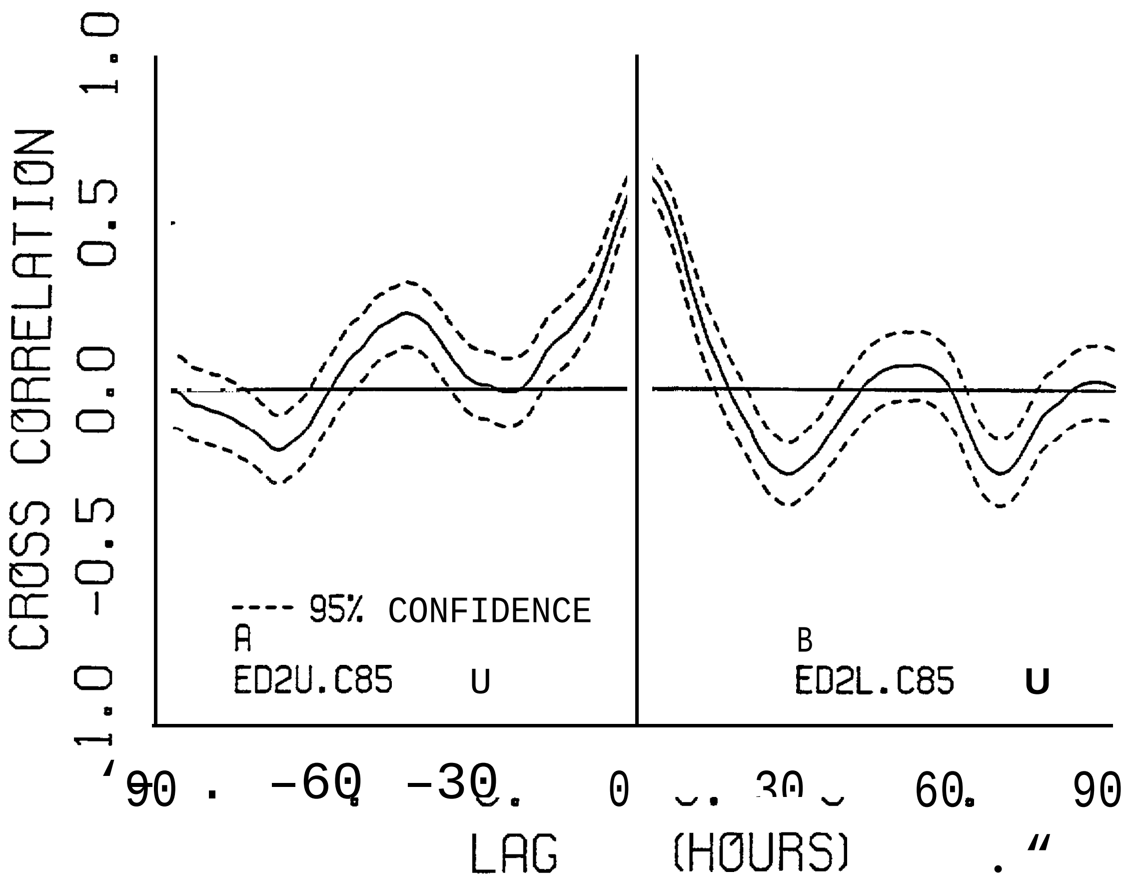


Figure 3-10. Cross correlation between U-component currents at ED2 upper and ED2 lower, 1985. **For positive lags, ED2 upper leads.**

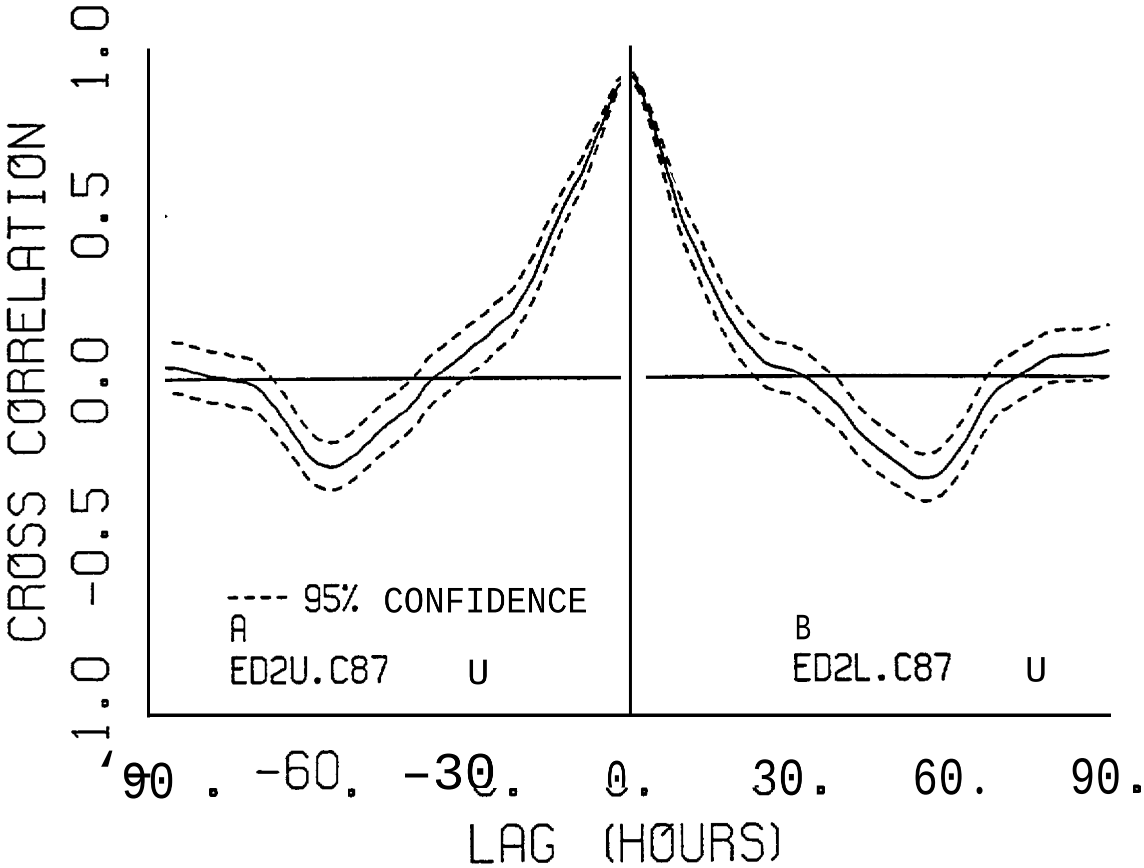


Figure 3-11. Cross correlation between U-component currents at ED2 upper and ED2 lower, 1987. For positive lags, ED2 upper leads.

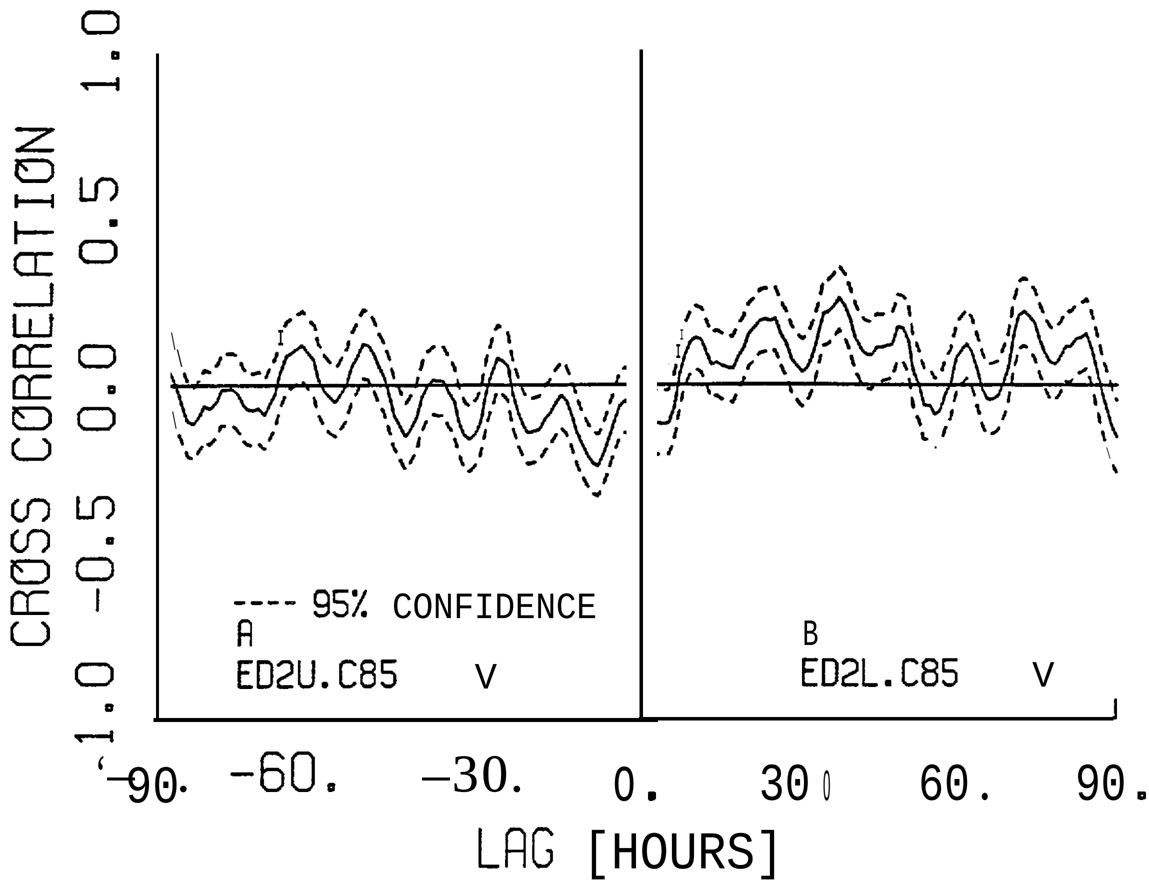
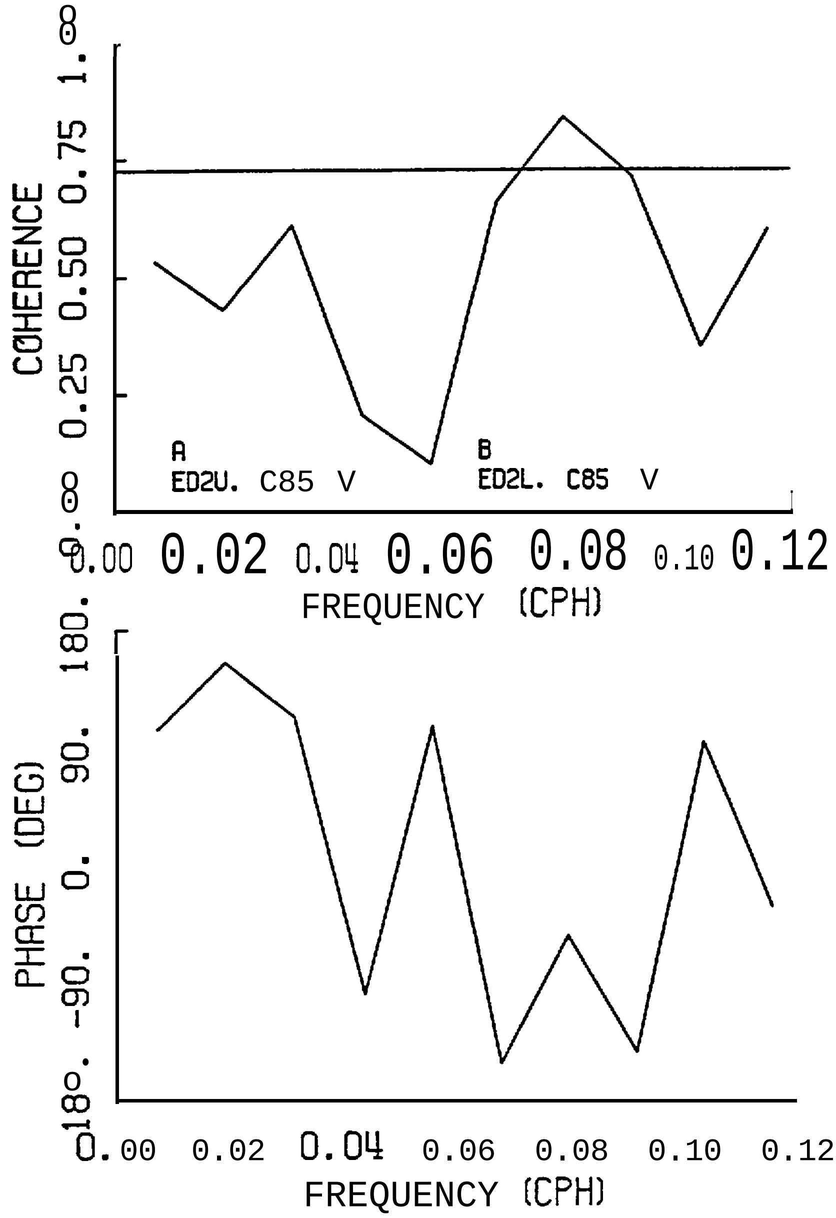


Figure 3-12. Cross correlation between V-component currents at ED2 upper and ED2 lower, 1985. For positive lags, ED2 upper leads.



"Figure 3-13. Coherence andphase between V-component currents at ED2upperand ED2 lower, 1985. Positive phase indicates ED2 upper leads.

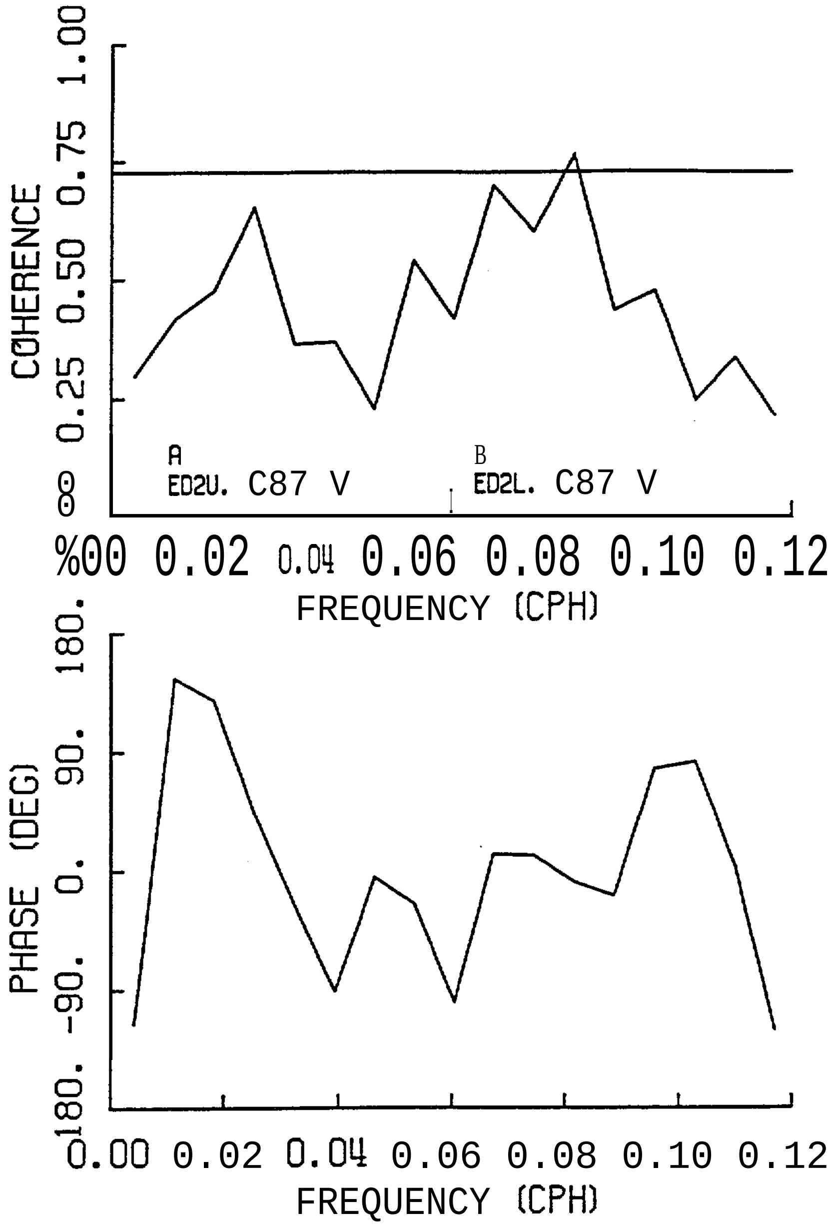


Figure 3-14. Coherence and phase between V-component currents at ED2 upper and ED2 lower, 1987. Positive phase indicates ED2 upper leads.

Cross correlation between U-components of upper and lower current meters at location CB6 (Camden Bay) in 1989 indicates the deeper current leading the upper current by 0 to 1 hours at maximum correlation of 0.59 (Figure 3-15). This result is opposite that in 1985 and 1987, when upper currents led deeper currents . In 1989, wind led upper currents by one hour, maximum correlation of 0.65 (Figure 3-16). For the same time interval, wind led lower current by five hours, maximum correlation of 0.48 (Figure 3-17). Based upon comparison of cross correlations between wind and currents at CB6 in 1989, upper current should lead lower current by approximately four hours, which disagrees with results of cross correlation calculations between the two current time series themselves.

One explanation for the apparent inconsistency is that wind and currents possess joint variance in one portion of the frequency spectrum, while the currents rpossess joint variance in another portion of the spectrum, and that the phasing is different between these two portions of the spectrum. Coherence and phase calculations indicate strong relation between the current records (Figure 3-18) in the low frequency band where wind and currents are generally related, but also between 0.10 and 0.11 cycles per hour. The autospectrum of the upper current meter U-component shows a relative energy deficit for periods between approximately 16-50 hours (Figure 3-19) tile the autospectrum for the lower current meter (Figure 3-20) shows a constant slope (no deficit) over the same range. Corresponding V-component spectra reflect the same feature, but less clearly.

The implication is that there is sufficient covariance in CB6 currents in the 0.10 to 0.11 cph frequency band, particularly because of the spectral content of the upper current, to dominate the cross correlation between upper and lower current records. Dimensions of Camden Bay, response to f luctuations in local riverine input, and the sheltered nature of location CB6 to the east are all potential factors influencing the correlation between upper and lower currents at CB6 in 1989.

3.3.3 Periodicities

3.3.3.1 Meteorological

Spectra for the U-component of wind for various analyzed years show no consistent significant spectral peaks, although the spectral content may indicate the presence of a given frequency in a given year. The strongest hint of a consistent interannual signal is at a frequency of about 0.007 cph, which corresponds to a period of approximately six days (Figure 3-21-1987 is representative; others, e.g., 1982 L1, 13, L4, L5, 1985 ER1 appear in Appendix A).

A signal at period of about 110 to 3.20 hours appears in autospectra of 1986 current records, particularly V-component (e.g., Figure 3-22), where the feature is not masked by other low-frequency energy, as is the case for corresponding U-component spectra. The corresponding local wind U-component autospectrum (Figure 3-23) also exhibits a peak at approximately this period, and at this period, it seems likely that wind forcing is the source of current variance.

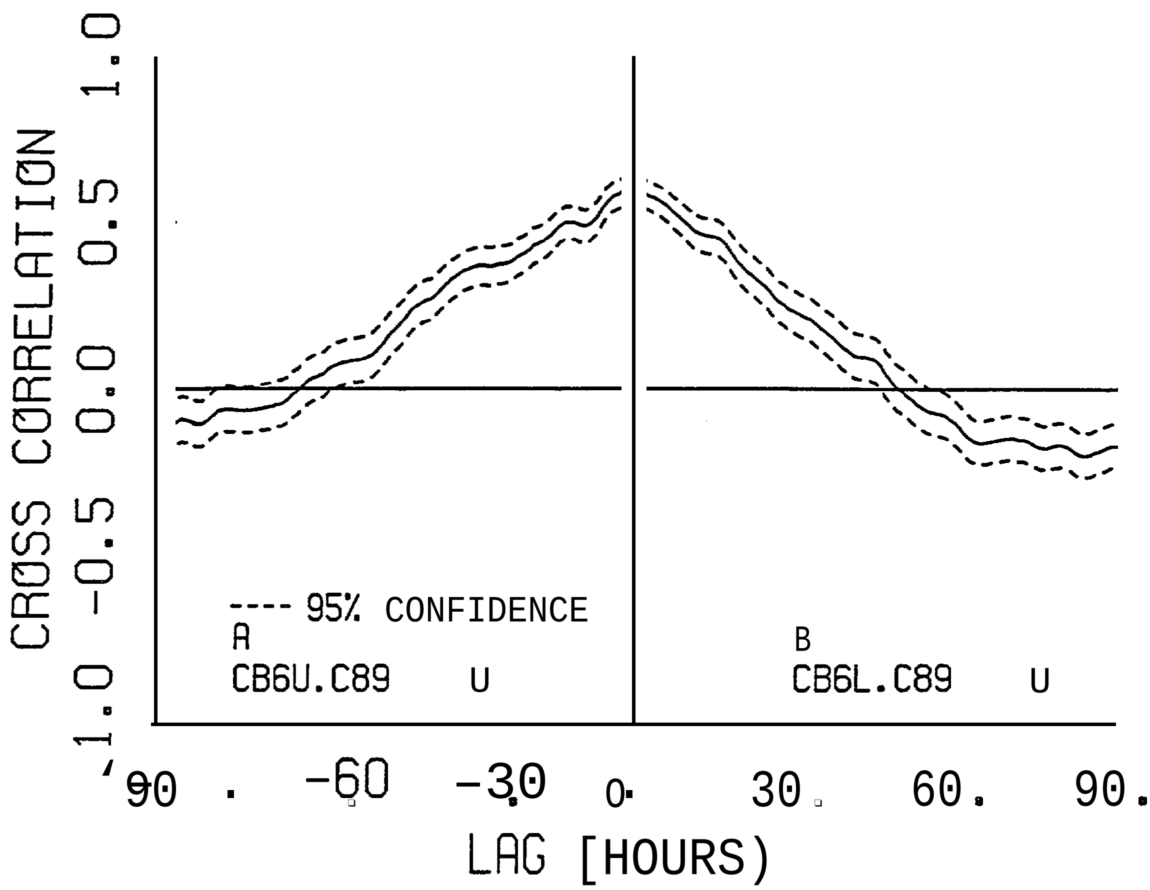


Figure 3-15. Cross correlation between U-component currents at CB6 upper and CB6 lower, 1989. For positive lags, CB6 upper leads.

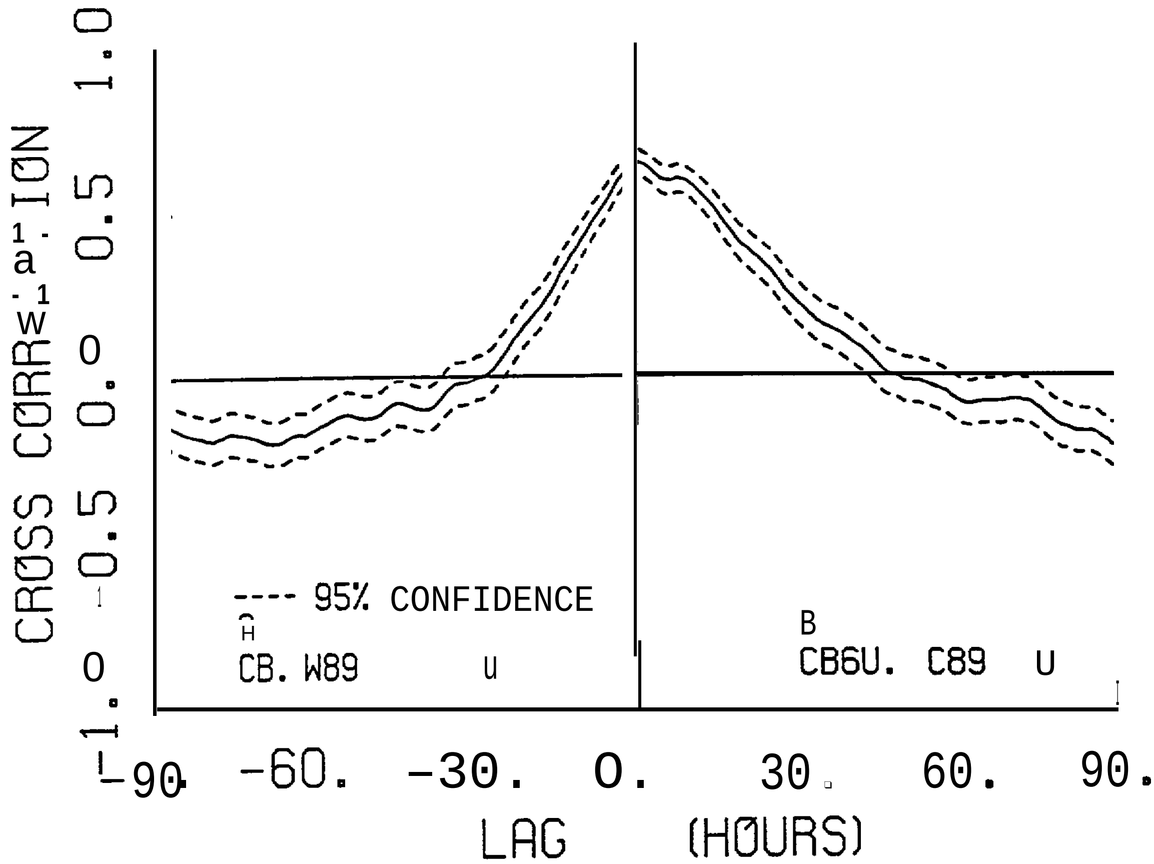


Figure 3-16. Cross correlation between U-components **of Camden Bay** wind **and CB6 upper currents, 1989. Wind leads for positive lags.**

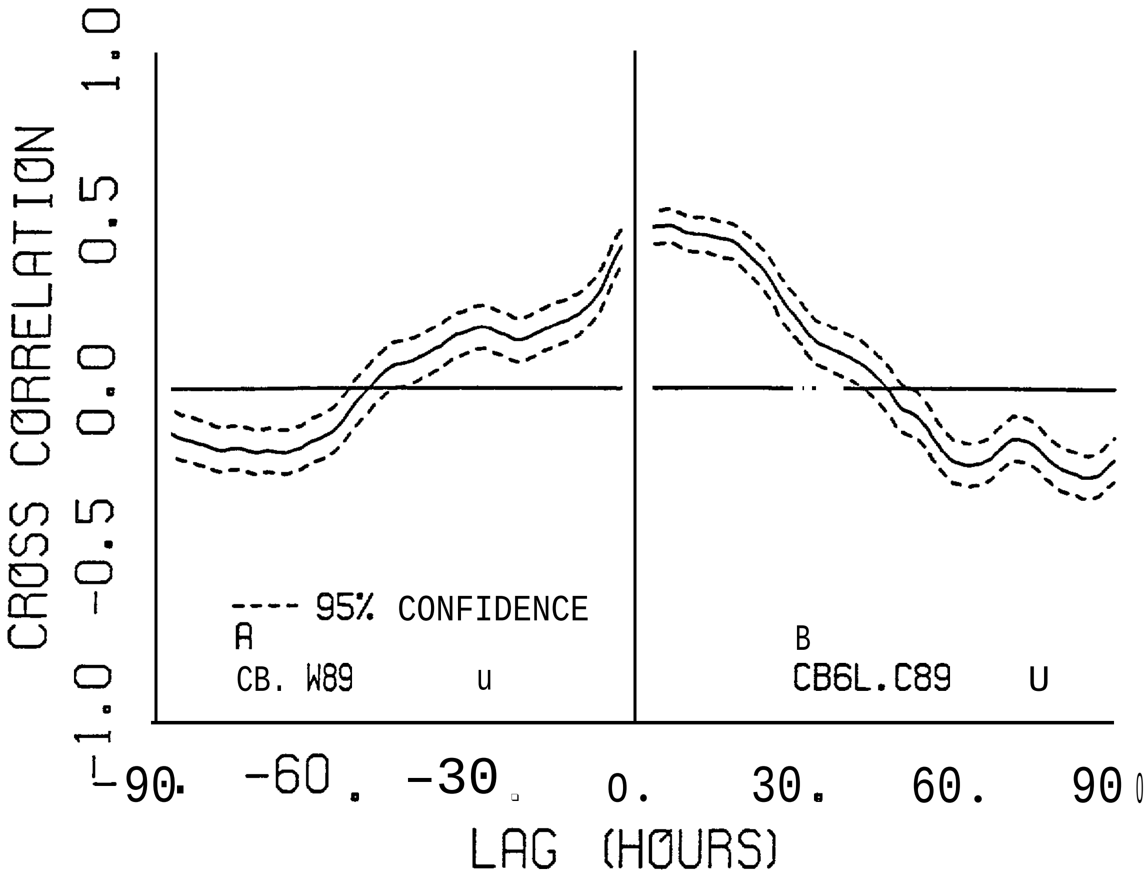


Figure 3-17. Cross correlation between U-components of Camden Bay wind and CB6 lower currents, 1989. Wind leads for positive lags.

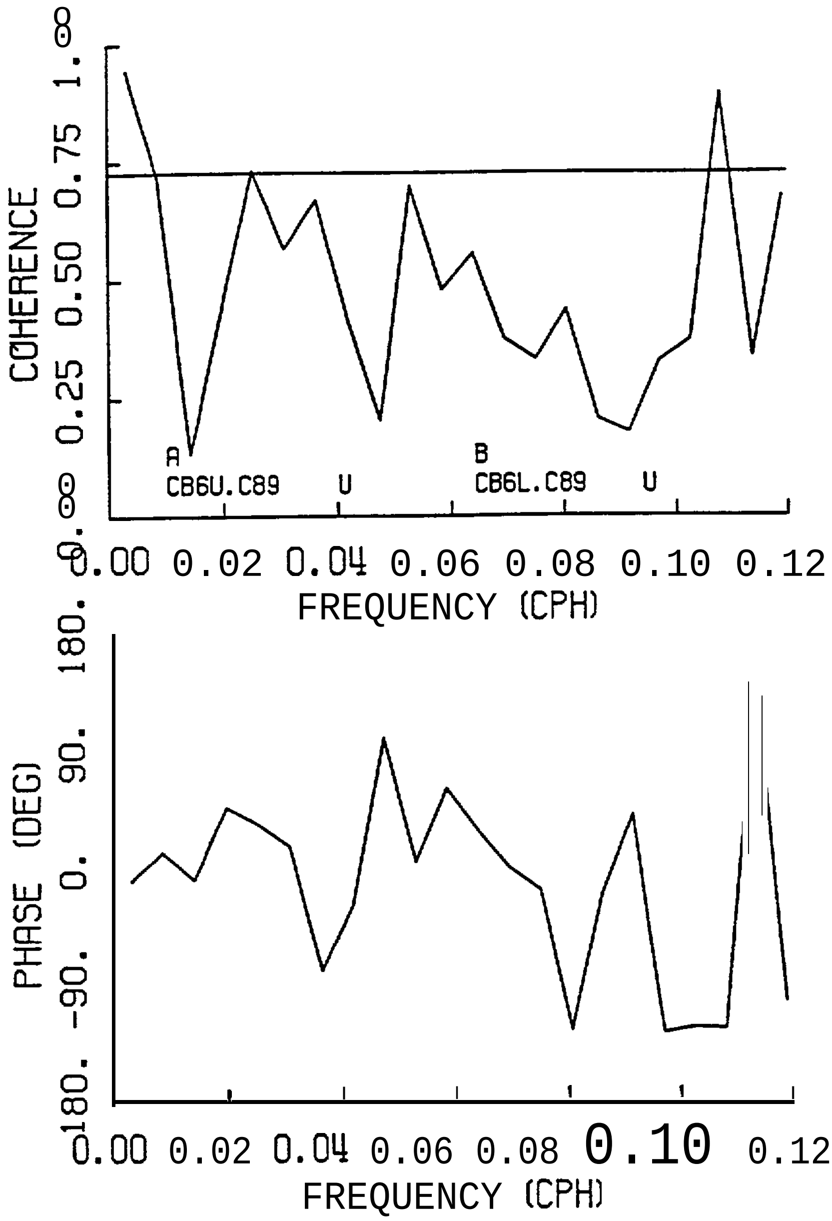


Figure 3-18. Coherence and phase between U-component currents at CB6 upper and CB6 lower, 1989. Positive phase indicates CB6 upper leads.

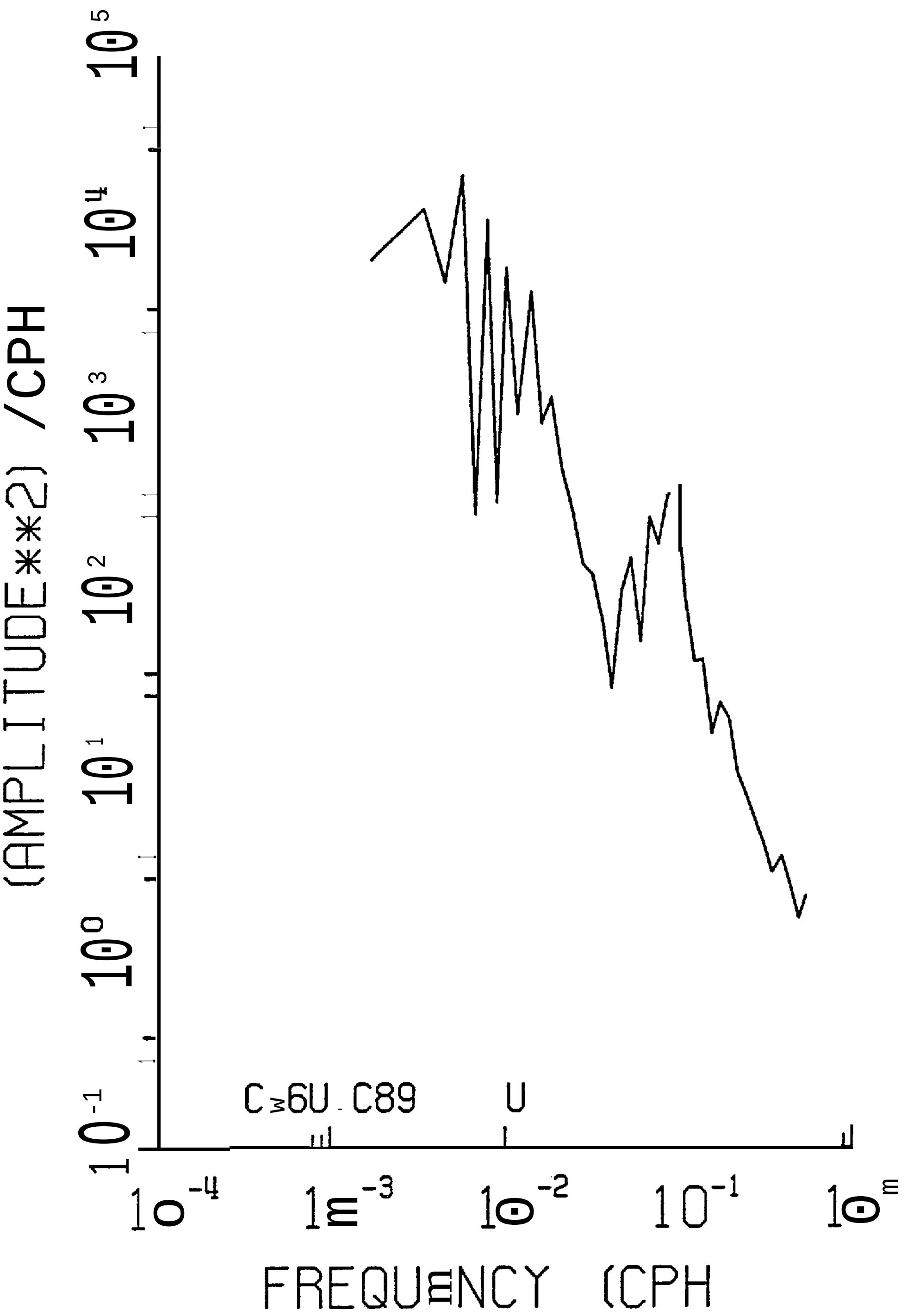


Figure 3-19. Autospectrum of U-component CB6 upper currents, 1989.

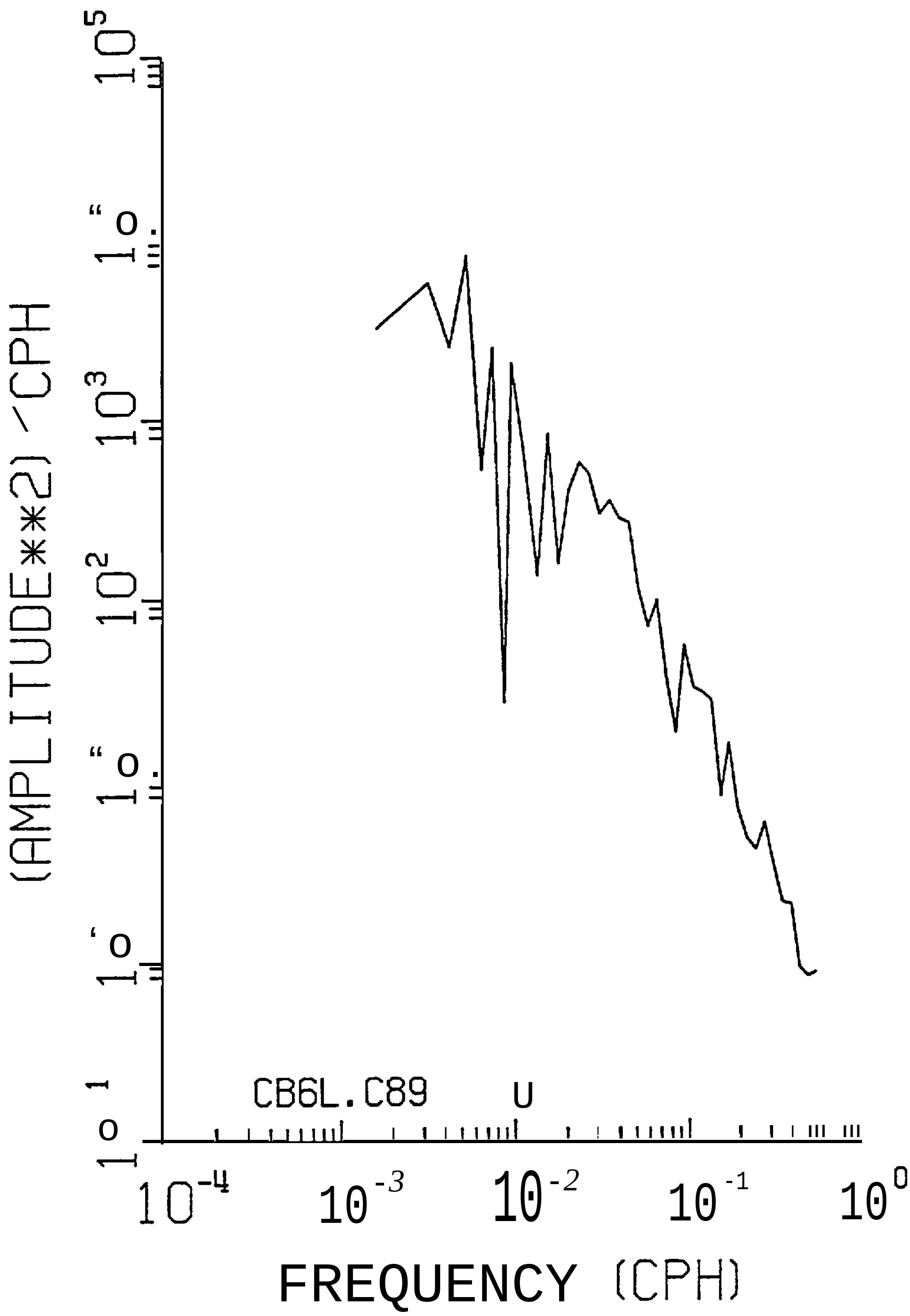


Figure 3-20. Autospectrum of U-component CB6 lower currents, 1989.

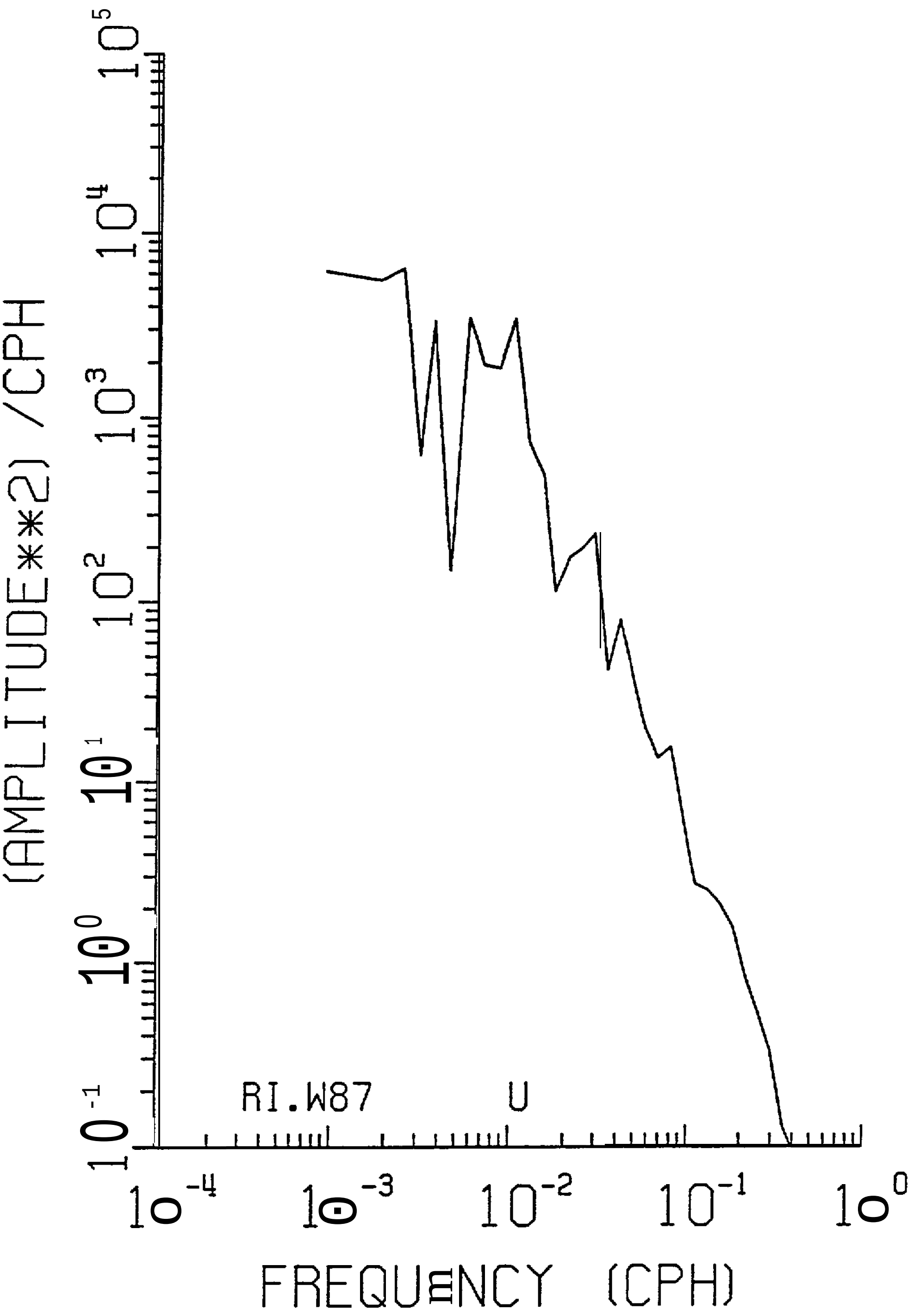


Figure 3-21. Autospectrum of U-component Resolution Island wind, 1987.

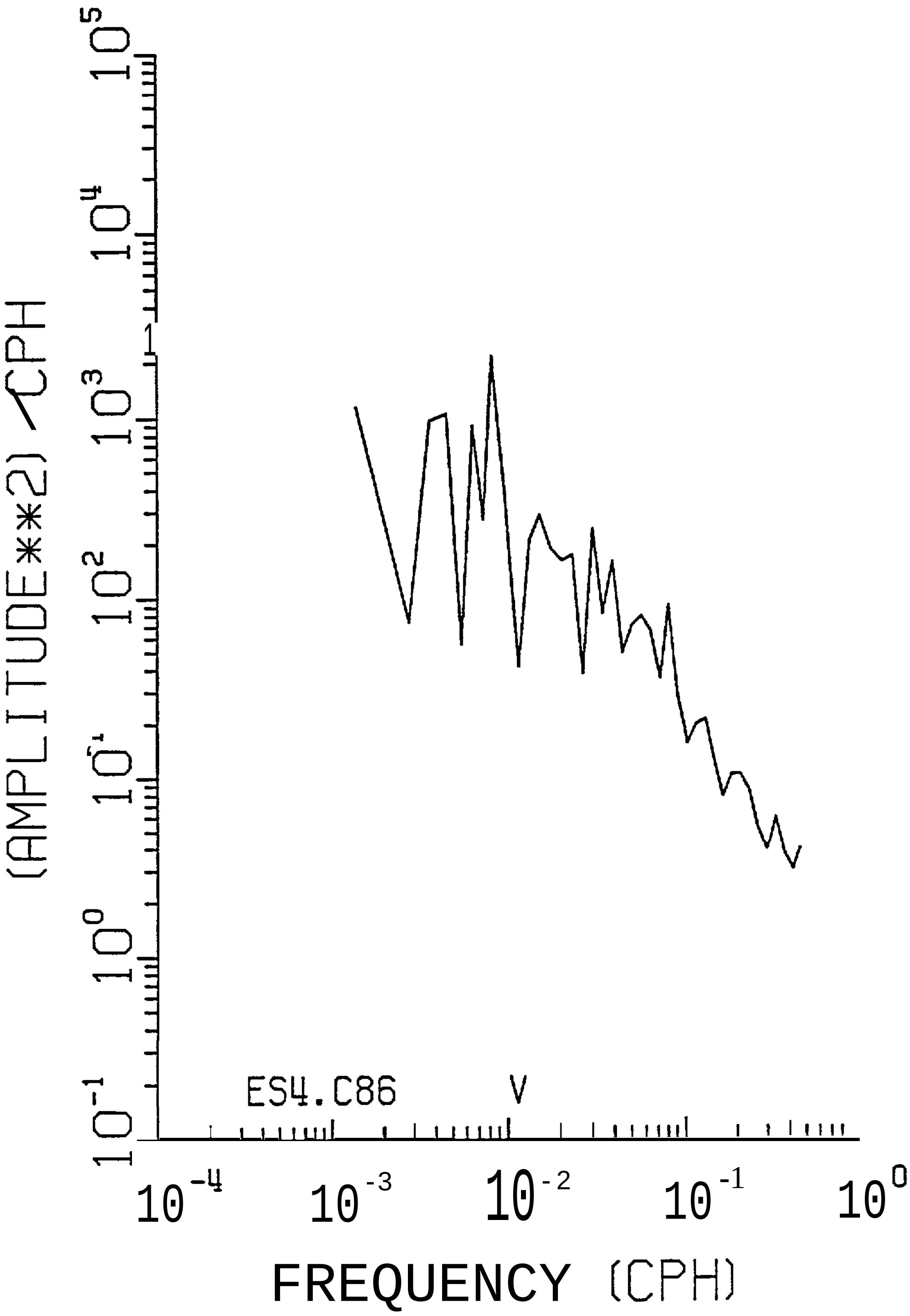


Figure 3-22. Autospectrum of V-component ES4 currents, 1986.

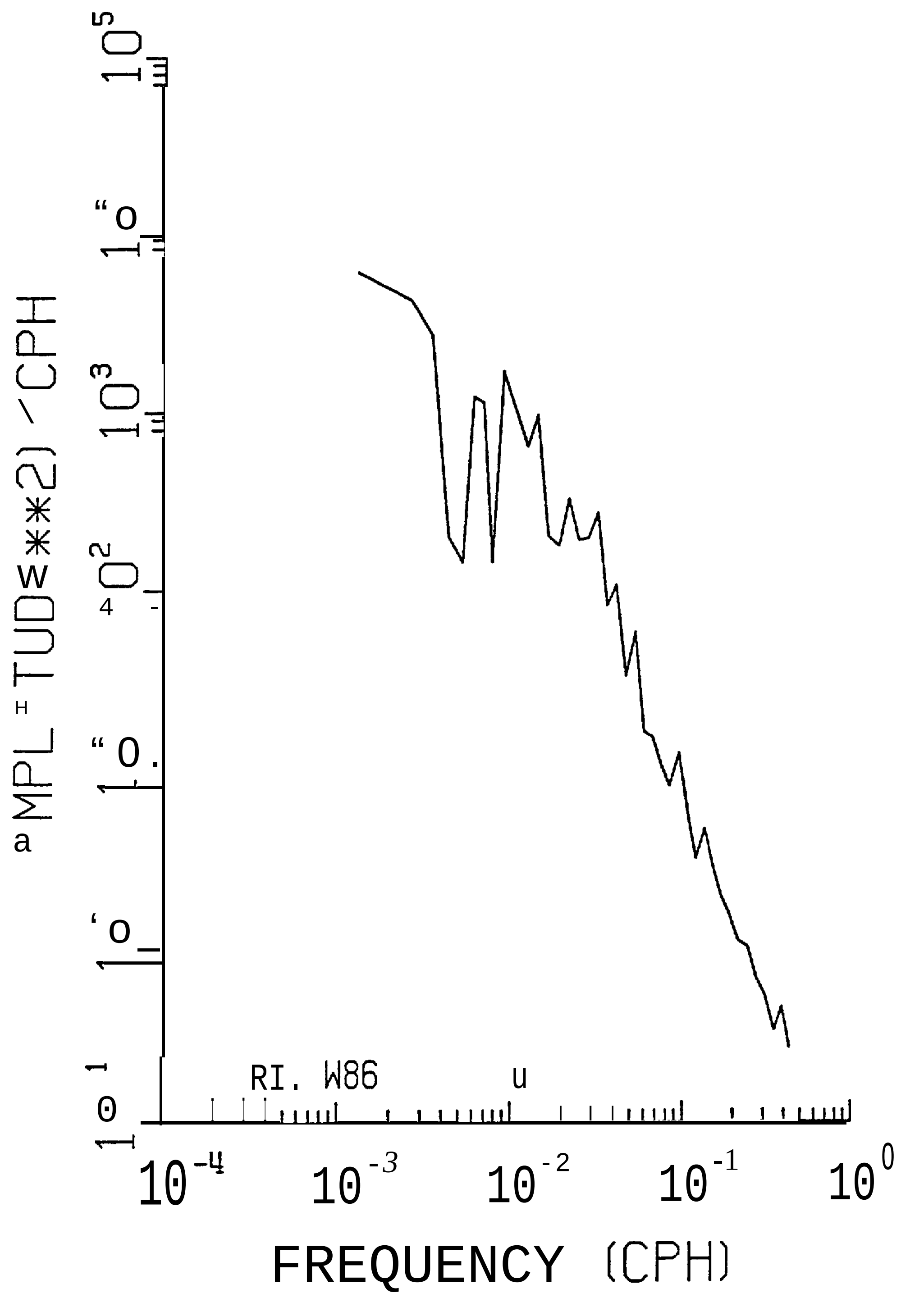


Figure 3-23. Autospectrum of U-component Resolution Island wind, 1986.

Similarly, there is a discernible peak in U- and V-component autospectra of the ED2 upper current meter data from 1987 at about 0.0078 cph, or 128 hour period (Figures 3-24 and 3-25). The corresponding local wind U-component spectrum (Figure 3-21) has a rather broad spectral peak that encompasses that same frequency. As in the 1986 data, it appears likely that wind forcing is the Source of current variance in this case.

These cases are individual examples drawn from different years. While the periods may be consistent with typical meteorological spectral characteristics, the very low frequency spectral values calculated here are not statistically significant. Thus, evidence and intuition point to wind being the major factor in current fluctuations in the nearshore area at periods greater than roughly 100 hours, but the inference is far from conclusive and caution should be used in interpreting the wind-current relation implied in the cases discussed above. The broadband nature of meteorological phenomena, with energy distributed over a period band ranging from a few days to more than a week can mask the presence of other low-frequency phenomena that contribute to current variability.

Coherence and phase calculations (Figures 3-9 and 3-26) from 1987 show that the major spectral relation between U-components of wind and currents is at frequencies of approximately 0.02 cph and less, which correspond to periods longer than a few days. Coherence diminishes between frequencies of 0.02 to 0.04 cph. corresponding phase spectra indicate that wind and currents are approximately in phase at low frequencies, but the general increase in phase angle with increasing frequency implies a lag of currents behind wind fluctuations as frequency increases. While confidence limits were not calculated for the phase plots, it is likely that they are on the order of plus or minus 15 degrees . This estimate assumes an average of fin successive raw values for each phase estimate (lo degrees of freedom) , corresponding coherence (not coherence squared) values Of 0.8 or greater, and reference to Fig. 9.3 of Jenkins and Watts 1968. Because of the potential error of several degrees in phase estimates, caution should be used in trying to determine exact phase relations between wind and currents.

The low-frequency relation indicated by coherence and phase results is borne out by the shape and initial decay of the respective cross correlation functions between wind and currents (Figures 3-7 and 3-27), in which the functions have maxima at near-zero lag and decay to zero within lags of about plus or minus 50 hours. The phase lag at maximum correlation evident from the cross correlations is 1-3 hours, with wind leading currents. This phase lag should approximately correspond to the actual phase difference at the maximum coherence value between wind and currents, which is at about 0.01 cph.

In view of the fact that wind accounts for up to about half the observed current variance in the analyzed records, there is no question that the low-frequency ends of the current spectra reflect low-frequency fluctuations in the wind. That there are not necessarily consistent sharp peaks at common frequencies in wind and current spectra indicates the broad band nature of wind forcing rather than the absence of a strong connection between the two.

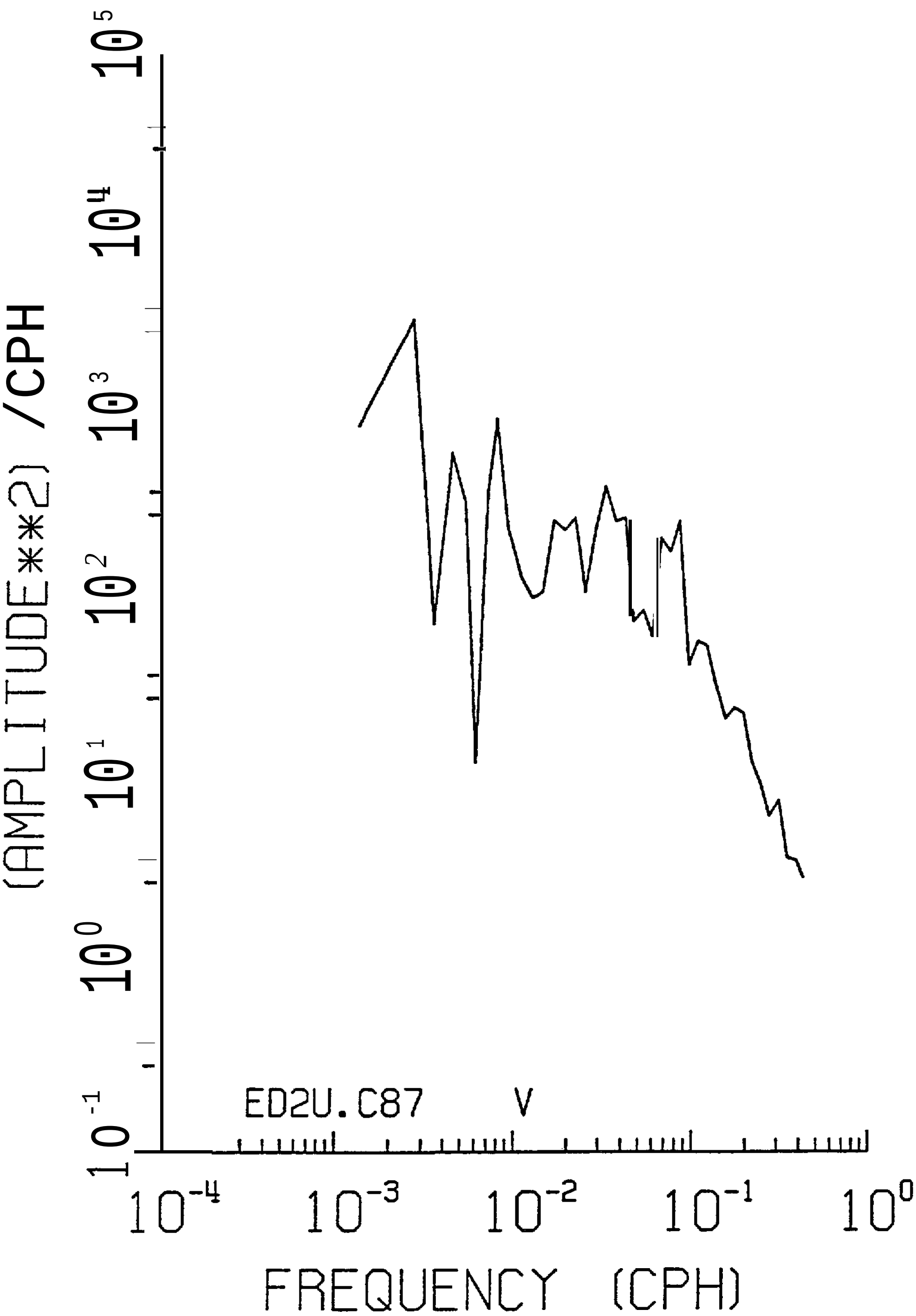


Figure 3-24. Autospectrum ○ V-component ED2 upper currents, 1987.

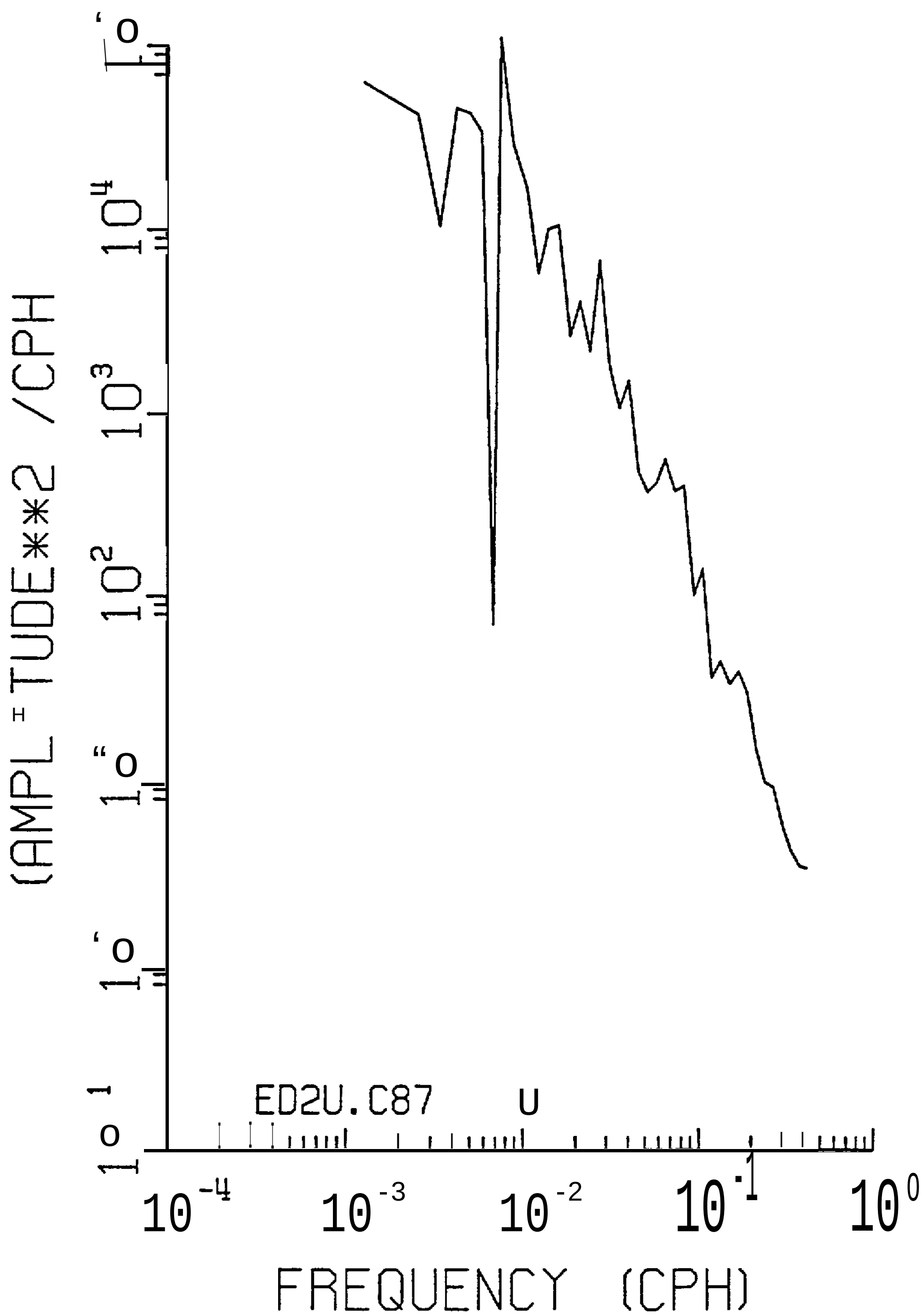


Figure 3-25. Autospectrumof U-component ED2 upper currents, 1987.

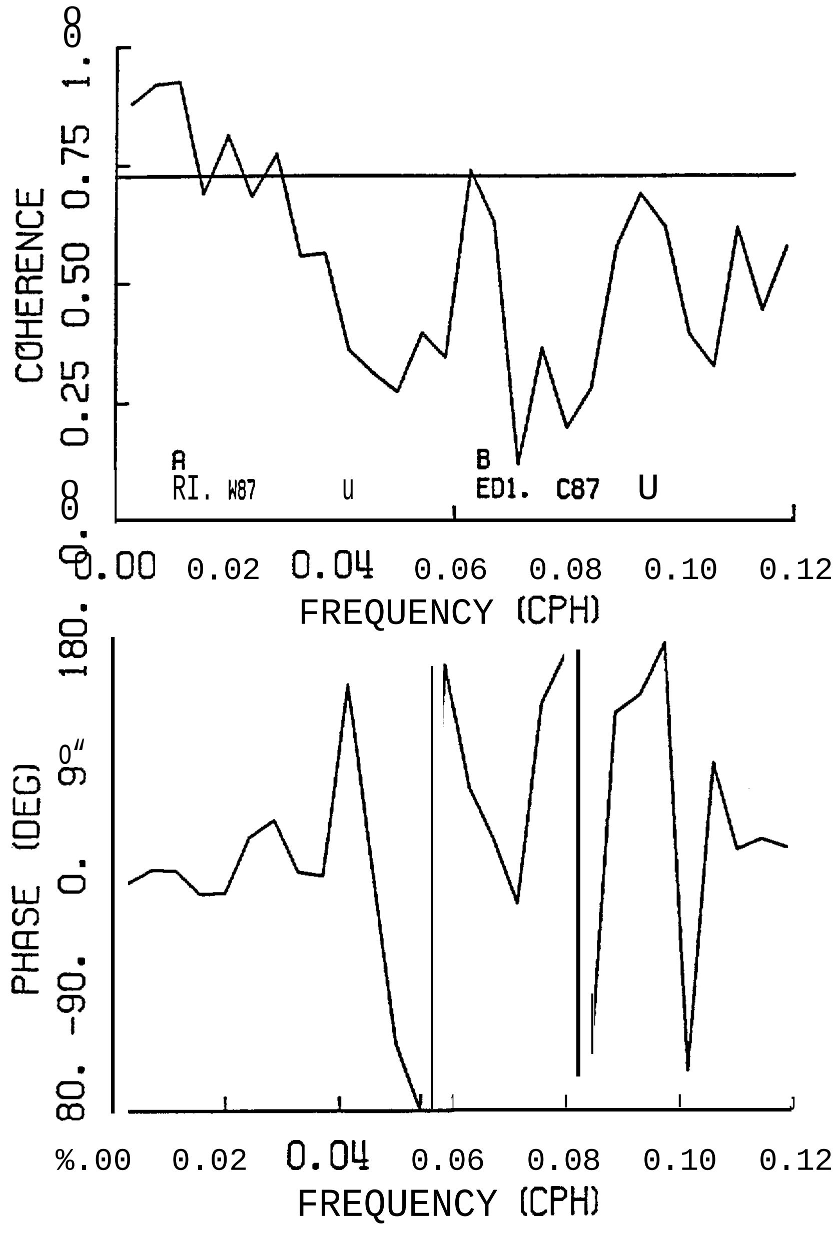


Figure 3-26. Coherence and phase between U-components of Resolution island wind and ED1 currents, 1987. Positive phase indicates wind leads currents.

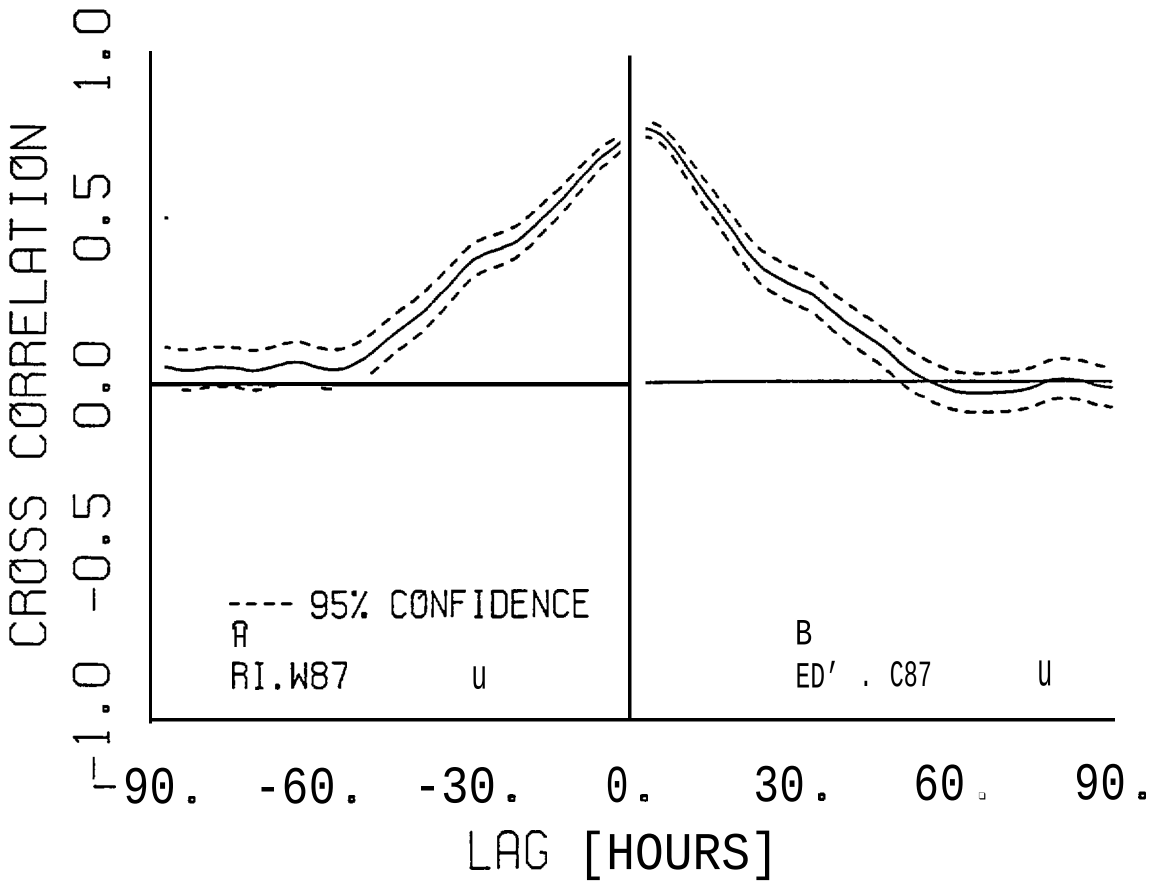


Figure 3-27. Cross correlation between U-components of Resolution Island wind and EDI currents, 1987. Wind leads for positive lags.

3.3.3.2 Tides

Tidal signals, particularly semi-diurnal as opposed to diurnal, appear in many of the current records, but primarily in the V-component along the minor axis, where meteorological influences are not as dominant. Energy at the semi-diurnal frequency is more apparent in the V-component autospectrum from ED2 (upper), 1987 (Figure 3-24) than in the corresponding U-component autospectrum (Figure 3-25). The appearance is deceptive because the semi-diurnal tidal energy in those respective autospectra is comparable, and the difference is due to the fact that distribution of energy over the low-frequency end of the U-component autospectrum masks the semi-diurnal tidal energy. In contrast, the energy content in the low-frequency portion of the V-component autospectrum decreases with decreasing frequency. Whereas, coherence and phase calculations between V-components of ED2(upper) and ED2(lower), 1987 (Figure 3-14) show the absence of coherent low-frequency energy in the upper and lower layers of the water column, they also show the expected presence of coherent tidal energy throughout the water column.

Autospectra of U- and V-components measured at L1,1982 (Figures 3-28 and 3-29) display the same general tidal nature as those for ED2, 1987, namely comparable semi-diurnal energy but with the U-component masked by the presence of low-frequency energy. Cross correlation from 1985 (Figure 3-12) reflects that the dominant common V-component signal in the shallow water column at ED2 is the semi-diurnal tidal signal.

3.3.3.3 Other

Signals of other periodicities can be identified in Current records from the various years sampled. Unlike tides, however, explanations for these other signals are more difficult to assign because of the transitory nature both of currents and potential external forcing mechanisms. Thus, a given mechanism may be active only part of a deployment internal or perhaps one year but not the next, and therefore the measured currents may not reflect its presence.

The results of various types of calculations suggest the year-to-year presence of a signal with a period of approximately 35 to 45 hours. For example, autospectra of U-components measured at L34 and 136, 1984 (Figures 3-30- 3-31) display common peaks at periods of about 43 hours (or 0.023 cph). Autospectra of U-component data from ED2, 1985 upper (Figure 3-32) and lower (Figure 3-33) current meters also have peaks at approximately the same period, but the cross correlation function for the two (Figure 3-10) and the autocorrelation function for ED2 lower, U-component, 1985 (Figure 3-34) show #e periodicity more graphically. Autospectra of U- and V-components at ED2 upper, 1987 (Figures 3-25 and 3-24) show similar peaks, and a corresponding rotary spectrum (Figure 3-35) indicates that energy is primarily in counter-clockwise motions.

The source of 35- to 45-hour periodicity is unclear. Autospectra of the U-components of local wind data for 1984 (Figure 3-36), 1985 (Figure 3-37), and 1987 [Figure 3-21) have peaks at periods of 50, 60, and 33 hours, respectively. Only in 1987 do the spectral characteristics of wind and currents coincide at

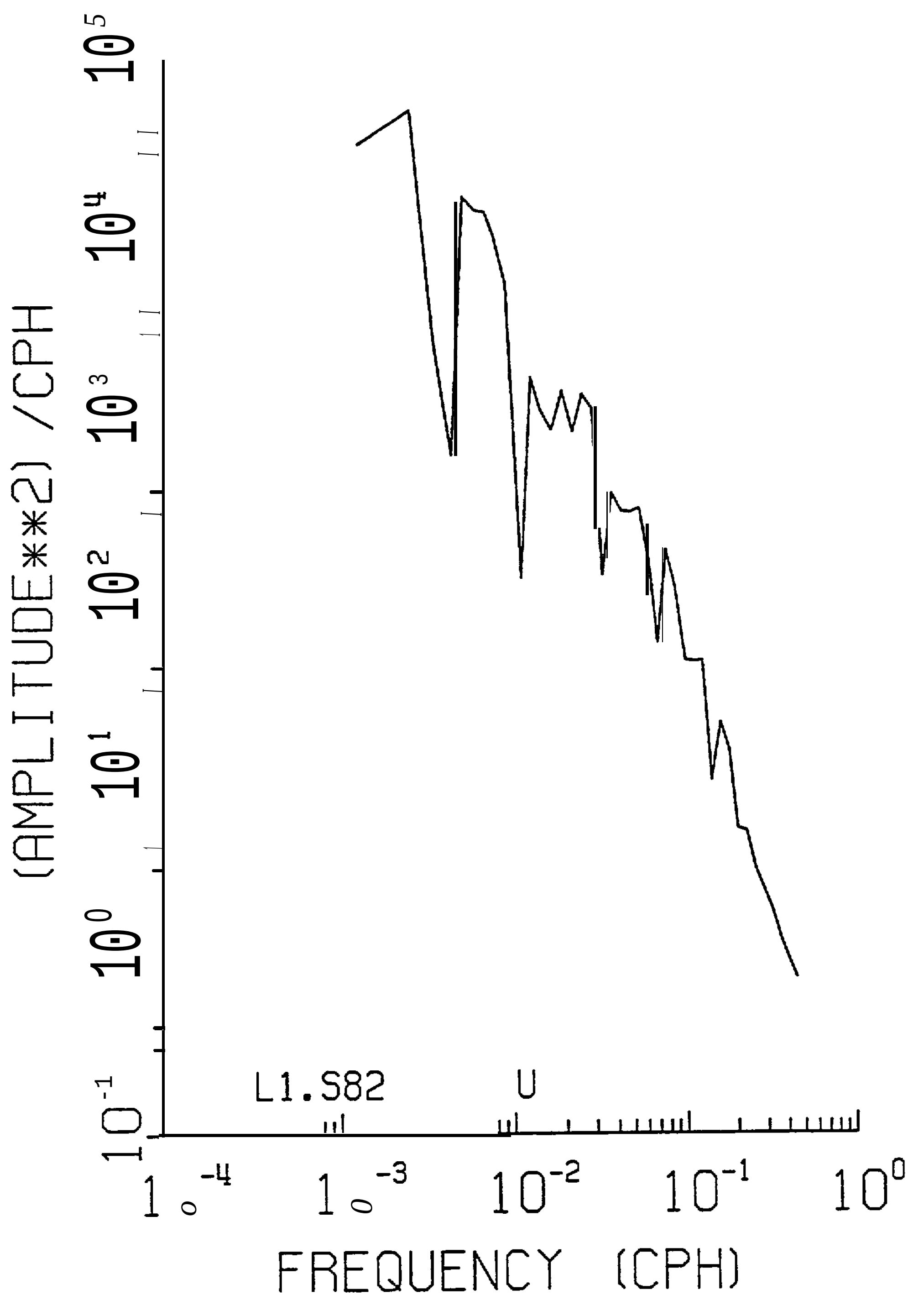


Figure 3-28. Autospectrum of U-component L currents, 1982.

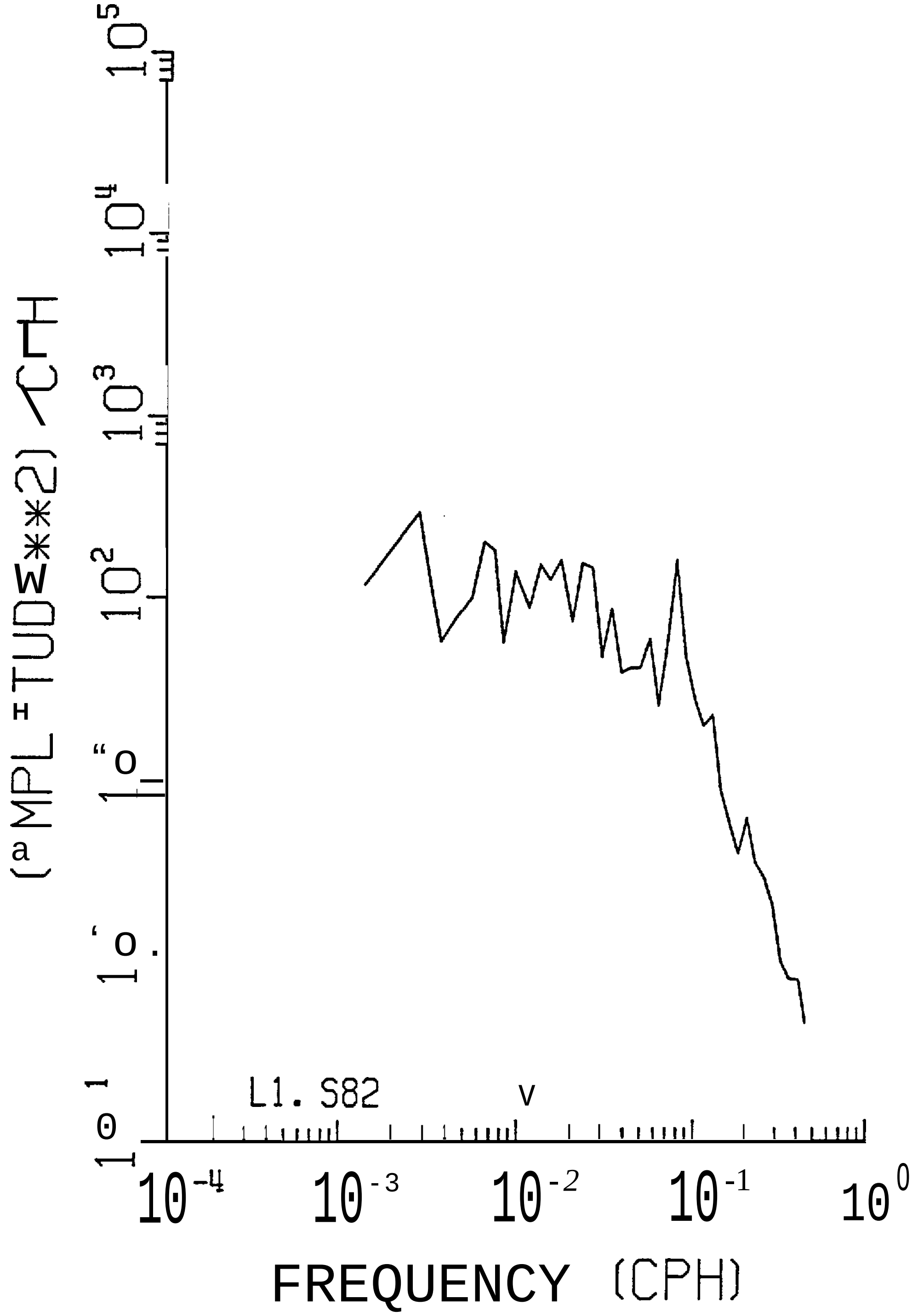


Figure 3-29. **Autospectrum** of V-component **L1 currents, 1982.**

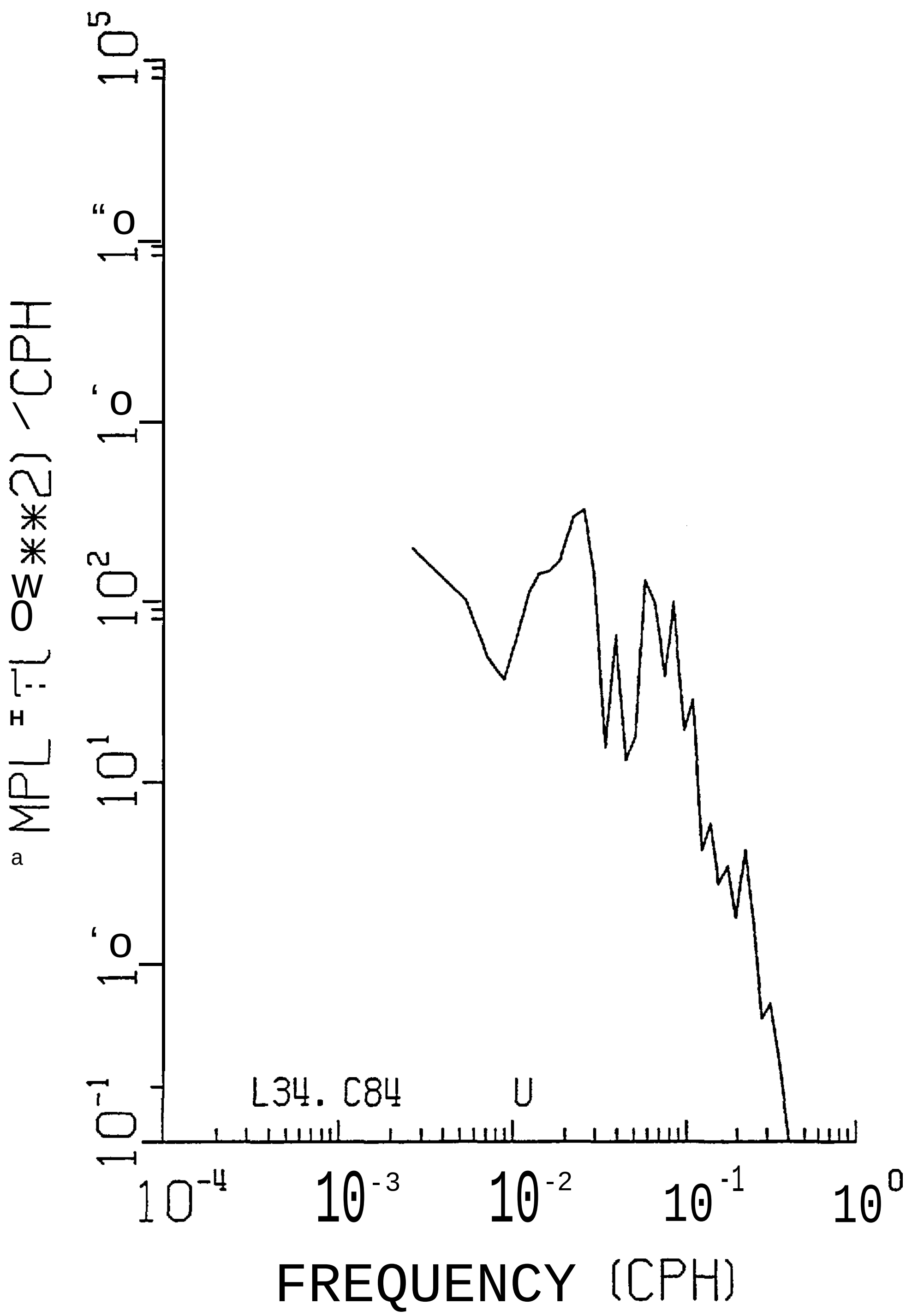


Figure 3-30. Autospectrum of U-component L34 currents, 1984.

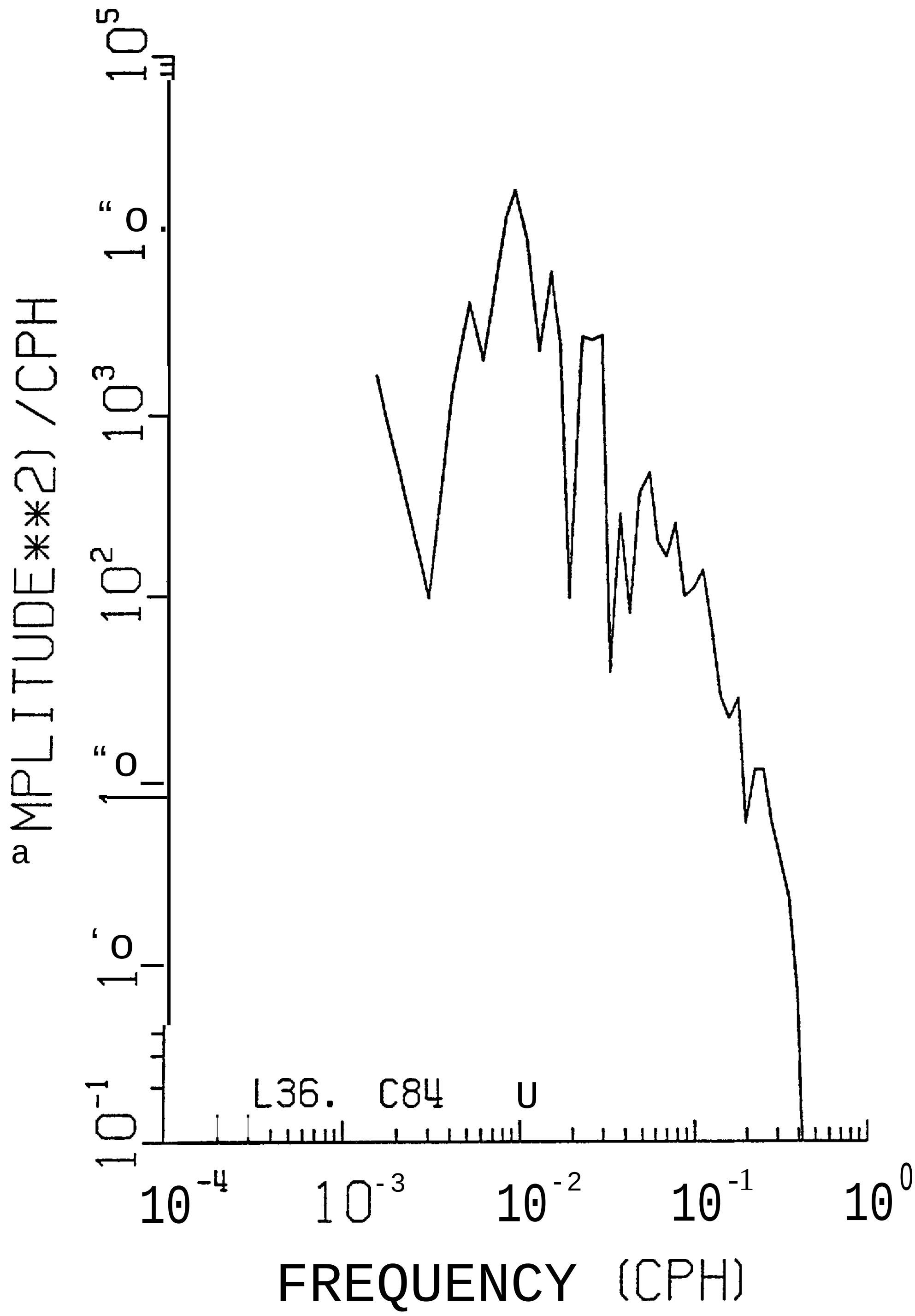


Figure 3-31, Autospectrum of U-component L36 currents, 1984.

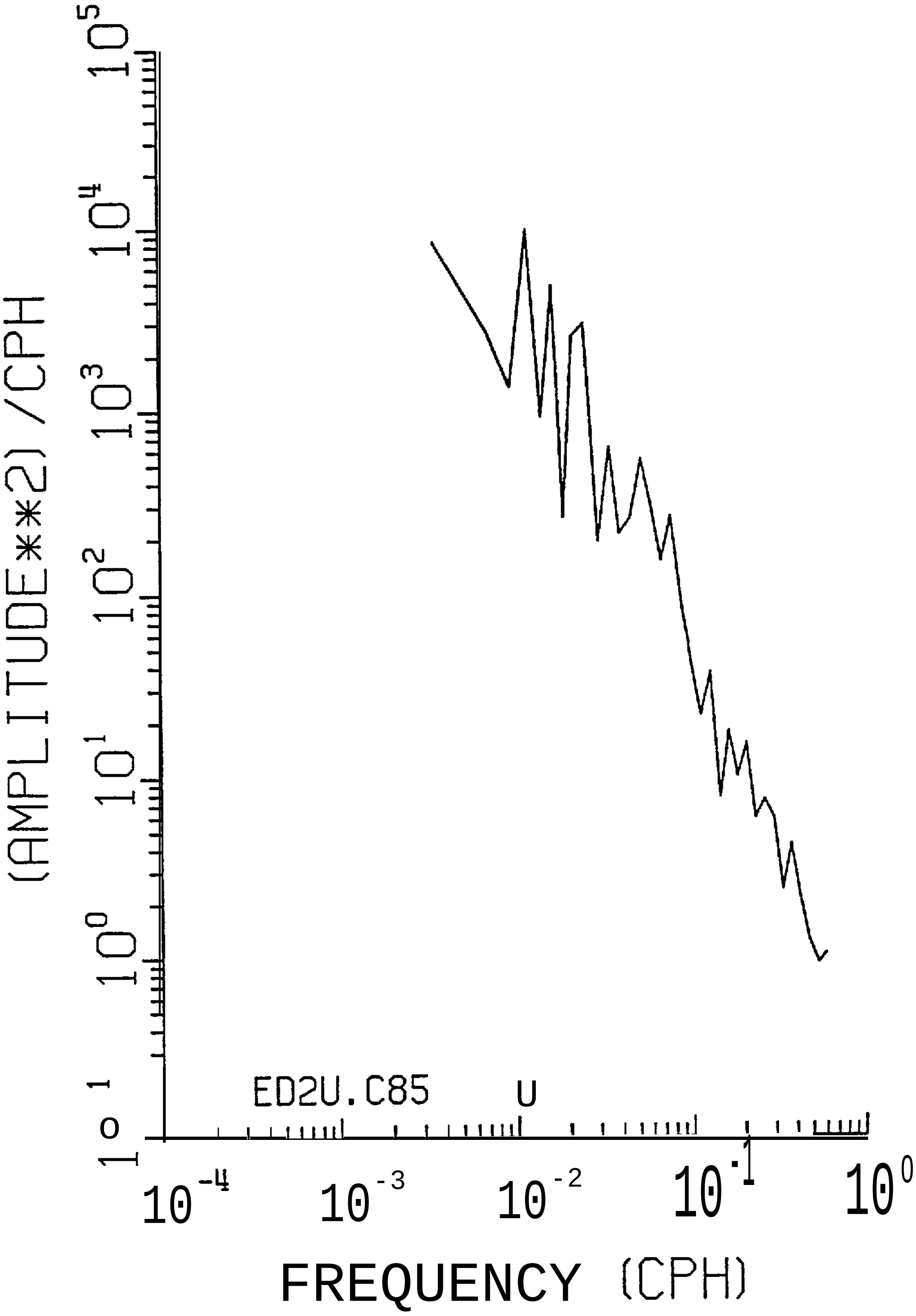


Figure 3-32. Autospectrum of U-component ED2 upper currents, 1985.

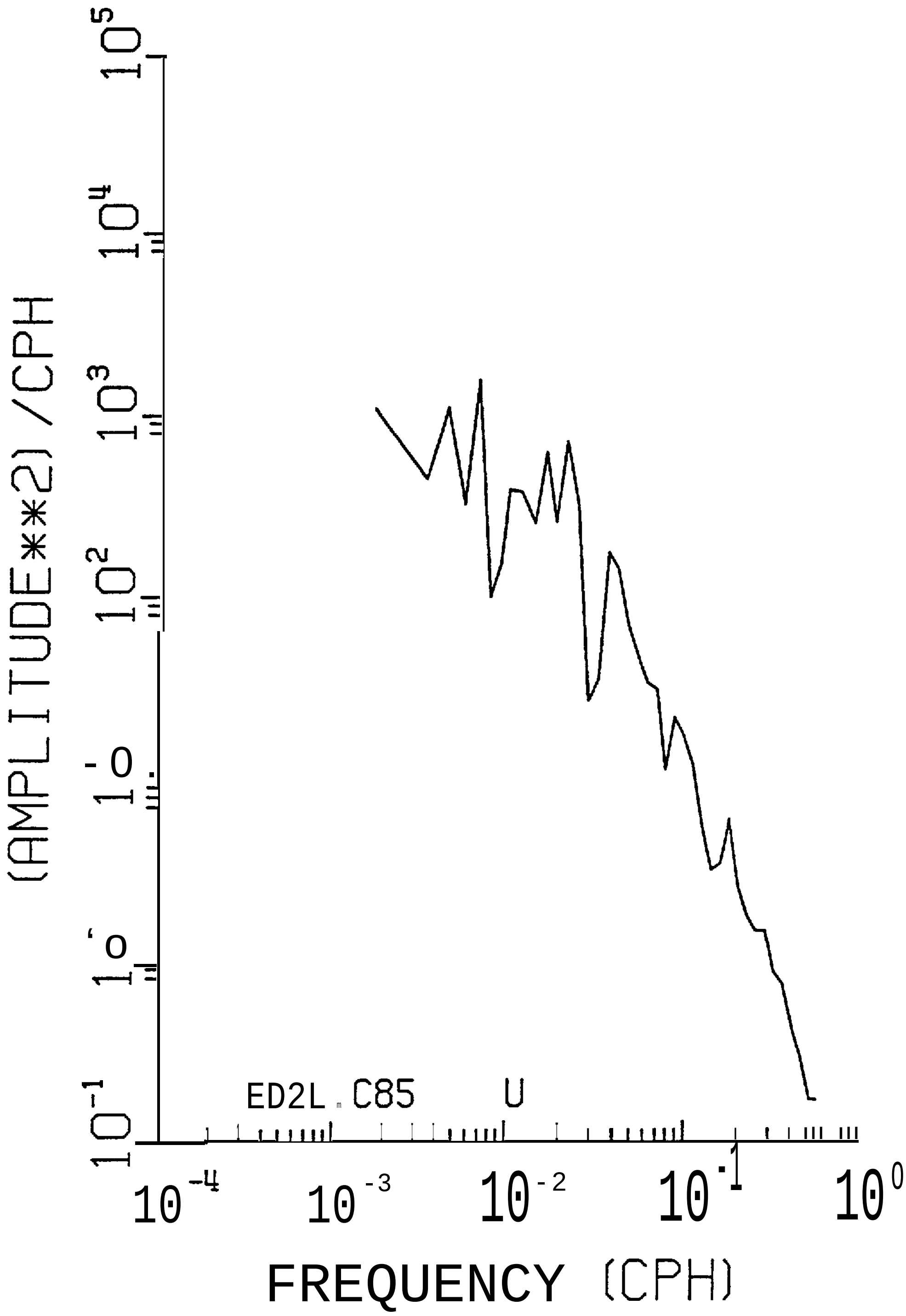


Figure 3-33. Autospectrum of U-component ED2 lower currents, 1985.

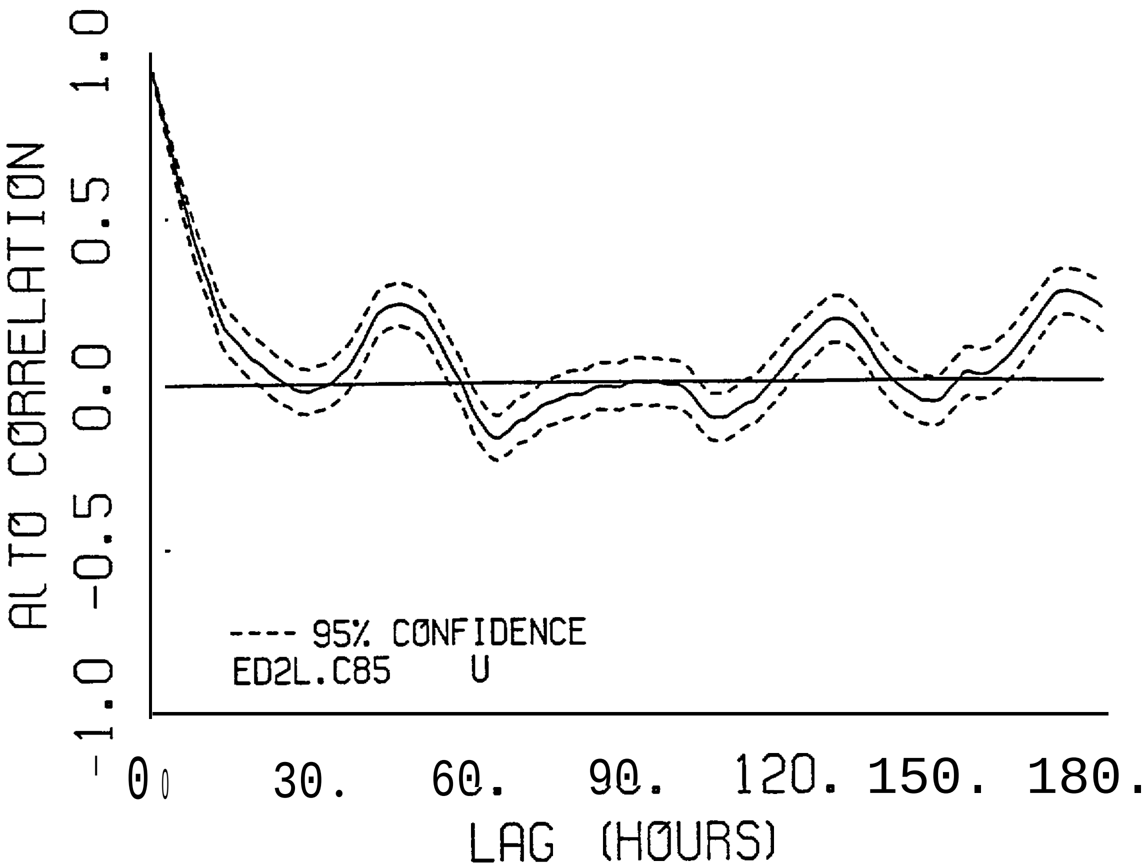


Figure 3-34. Autocorrelation of U-component ED2 lower currents, 1985.

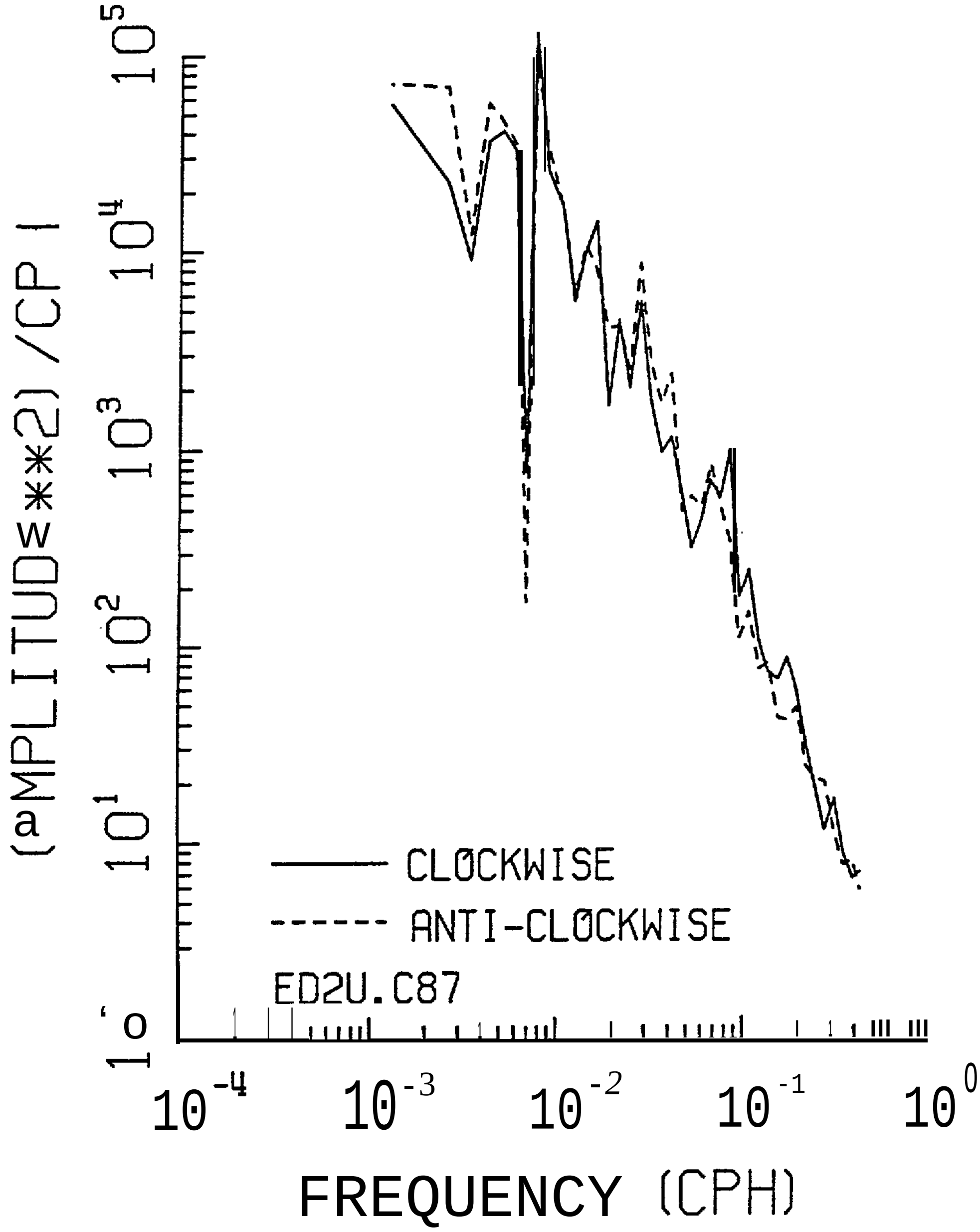


Figure 3-35. Rotary spectrum of ED2 upper currents, 1987.

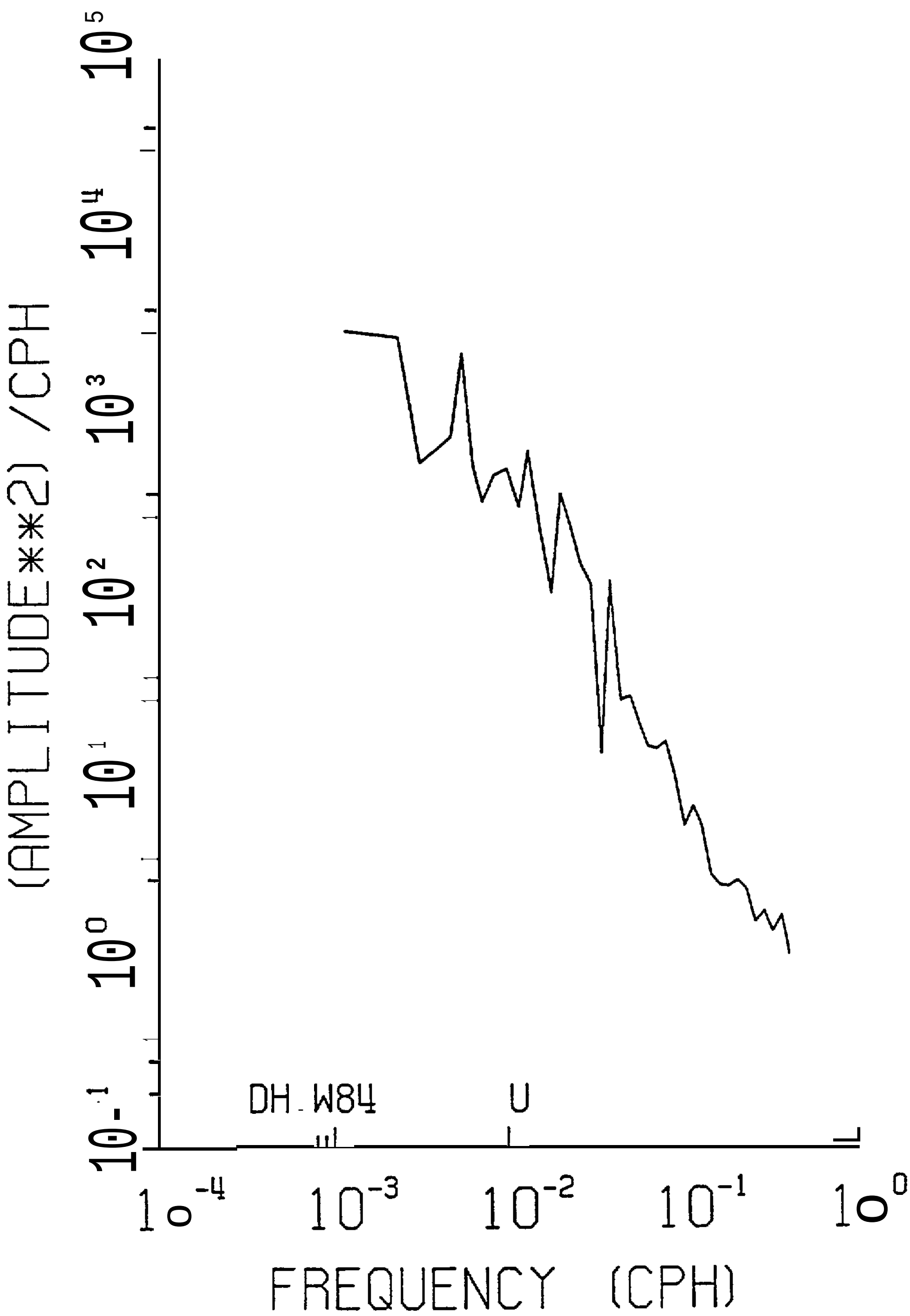


Figure 3-36. Autospectrum of U-component Deadhorse Airport wind, 1984.

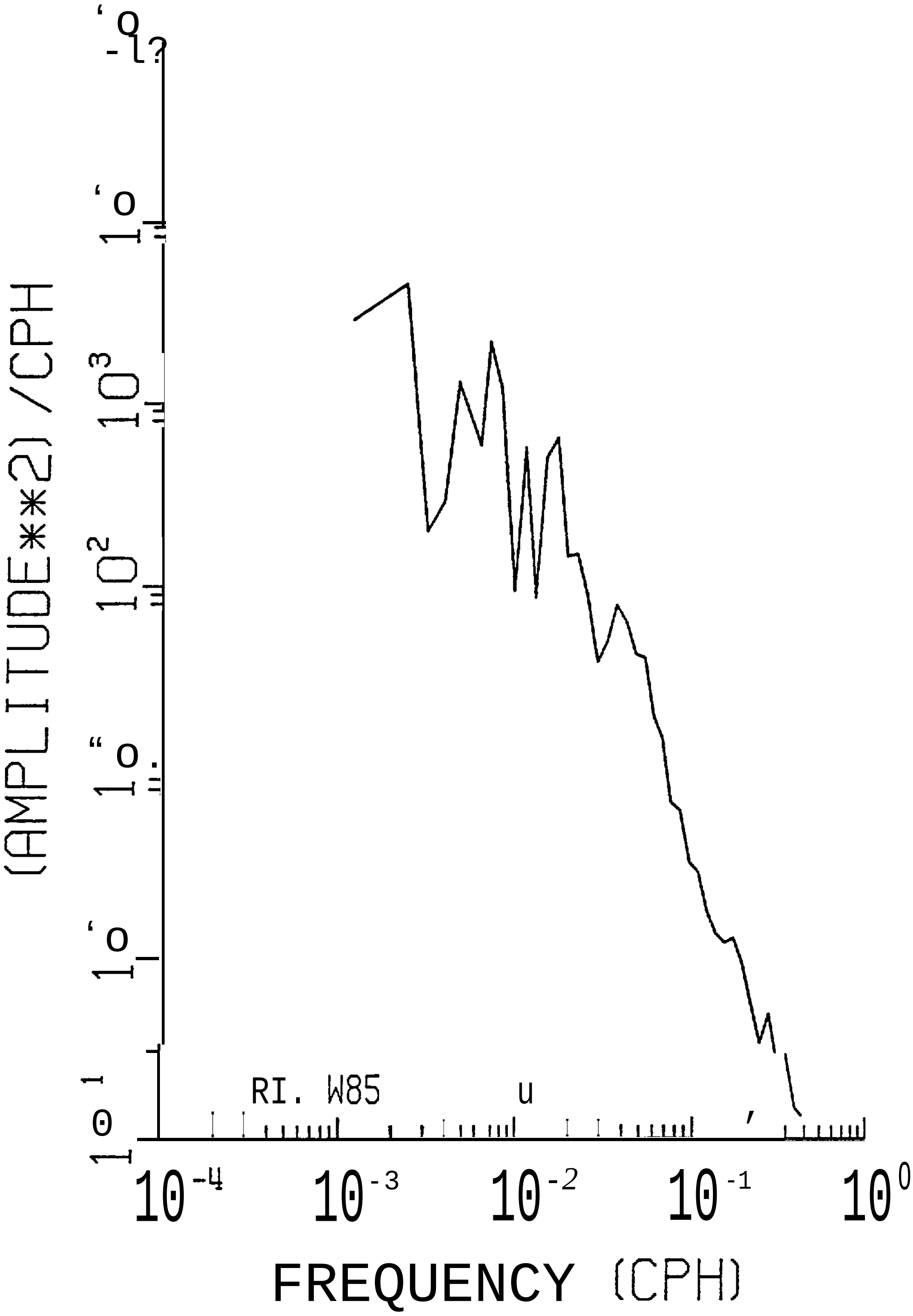


Figure 3-37. Autospectrum of U-component Resolution island wind, 1985.

approximately the 35- to 45-hour period range, and the significance of the peak at 33-hour period is questionable. Also, in 1984 -1985, wind accounted for less than 10 percent of the variance of deeper currents (Table 3-8), so that direct wind-forcing in that period range might not be expected to be significant. On the other hand, it is important to point out that, in 1987, local wind and currents at ED2 upper were significantly coherent at 0.0274 cph, which corresponds to a period of 36 hours. Thus, wind forcing can neither be confirmed nor denied as the source of variance in the 35- to 45-hour period range, even though periods in this range seem short compared with expected meteorological pericdicities. Another possibility is an eastward-propagating trapped-wave disturbance, and indeed, coherence and phase calculations for 1984 data show significant coherence between currents separated in the alongshore direction, with currents at the western mooring leading by a few hours. Existing data do not allow unequivocal isolation of the source of observed variance in the 35- to 45-hour period range.

3.3.4 Topographic infects

3.3.4.1 Principal Axis orientation

In the nearshore area, the combination of bottom topography and proximity to the coastline clearly influence current direction. Approximate orientation of local bottom contours and principal axis directions for the respective current records show a close correspondence in most cases (Table 3-9). Thus, the most energetic fluctuations tend to be along bottom contours, which also roughly coincide with the coastline. All tend to be oriented northwest-southeast.

3.3.4.2 Vector-averaged Direction

In many cases, the vector-averaged current direction also aligns with local bottom contours, but not with the same consistency as principal axes (Table 3-9). (Principal axis angles are reported between 0 and 180 degrees tree, so an addition of 180 degrees is necessary when comparing with current directions between 180 and 360 degrees true.) Disparity between vector-averaged directions and bottom contours in part reflects low frequency background motion that may be due to an alongshore pressure gradient, for example.

3.3.4.3 Wind and currents

In contrast to principal axis orientations of currents, which tend to be northwest-southeast, principal axes for wind lie between 60 and 93 degrees true (Table 3-9). While wind fluctuations tend to have a strong cross-isobath component, currents are rectified into the alongshore directi"on, although it is important to keep in mind that wind-forcing is far from being the sole source of current motions. In spite of this caveat, and taking into consideration previous results showing that wind does indeed account for a large portion of current variance in near-surface current meter records, the role of topography in steering wind-f orced currents is apparent.

Table 3.9 **Summary of wind and current** principal axes, means, **and** approximate **bottom** contour orientation.

Note: All **directions are in degrees true and represent** direction **toward which the velocity vector points for both wind and current. Speeds are in centimeters per second except where entered as meters per second (m/s) for wind. Bottom contour directions are in degrees clockwise from north.**

YEAR Record	PRINCIPAL Axis Length	Dir	% Variance	VECTOR AVERAGE Speed	Dir	BOTTOM CONTOUR Dir
1989						
CB.W89	3.4	43	87	1.4 m/s	213	
CB6U.C89	10.8	110	75	1.2	129	75
CB6L.C89	6.9	93	62	0.9	336	75
CB2. C89	7.0	104	96	2.8	103	100
1988						
CB.W88	5.0	76	87	1.6 m/s	228	
CB6L.C88	6.5	50	59	2.5	97	75
1987						
RI.W87[1/]	6.1	80	77	1.0 m/s	191	
ED2U.C87[1/]	24.2	129	95	3.2	91	130
RI.W87[2/]	5.6	77	73	1.5 m/s	96	
ED2U.C87[2/]	24.6	130	94	8.1	110	130
ED2L.C87[2/]	13.9	107	82	4.3	123	130
ED1. C87	14.3	140	88	5.2	278	140
ED3U.C87	25.9	126	96	7.8	110	3.20
1986						
RI.W86	5.5	93	77	1.6 m/s	241	
ED1.C86	12.1	139	88	3.5	344	140
ES6.C86	10.5	3.24	92	6.0	314	85
ED3.C86	21.1	125	96	2.9	328	125
ES4.C86	8.5	93	78	1.9	314	105
ER4.C86	17.3	44	93	3.1	202	120
1985						
RI.W85	3.8	82	80	3.1 m/s	235	
ED2U.C85	3.2.5	130	95	6.8	311	140
ED2L.C85	4.2	102	72	2.0	7	140
ER1.C85	6.6	160	81	3.2	18	140

(continued)

Table 3-9, continued. Summary of wind and current principal axes, means, and approximate bottom contour orientation.

Note: All directions are in degrees true and represent direction toward which the velocity vector points for both wind and current. Speeds are in centimeters per second except where entered as meters per second (m/s) for wind. Bottom contour directions are in degrees clockwise from north.

YEAR	PRINCIPAL AXIS			VECTOR AVERAGE		BOTTOM CONTOUR
Record	Length	Dir	% Variance	Speed	Dir	Dir
1984						
DH.W84	4.7	72	79	1.7 In/s	233	
GI .W84	4.9	74	81	2.0 m/s	232	
L32. C84	3.3	93	90	0.7	102	110
L34.C84	3.5	104	70	0.6	82	100
136. C84	11.3	110	90	0.1	200	115
1982						
RI.W82	5.2	61	84	2.3 111/S	231	
L1. C82	14.1	146	95	2.3	333	1.25
13. C82	17.9	121	97	1.9	256	130
L4.C82	11.8	1.53	79	4.4	4	135
L5.C82	10.2	102	86	4.2	275	I-25

1/ Record starts at 0000 on 25 July 1987.
2/ Record starts at 2100 on 12 August 1987.

3.3.5 Spatial current Correlations

3.3.5.1 Alongshore

Analysis of the small number of data records separated alongshore indicates that the currents at the westernmost of a mooring pair tend to - thoseat the mooring farther east. In one example from 1987, ED3 upper U-component leads that of ED1, about 11 km east, by one to two hours (Figure 3-38). This represents a phase speed of about 2 m/s. Similarly, in 1982, L5 U-component leads L4 by one to two hours. Mooring L5 is about 8 km west of L4. However, from 1982, L1 U-component lags L3 by thee hours, which is opposite the expected trend. In view of errors in recording true start times for L1 and L3, the deviation may simply be due to a lag pre-imposed by erroneous start times. From 1984, L32 UU-component leads L36, about 33 km farther east, by only about an hour at maximum positive cross correlation of +0.35, but by 55 hours at maximum negative correlation of -0.42. These two current records are both from depths of 4.6 m in water 6 m deep, and direct wind-forcing does not appearto contribute significantly to the variance (Table 3-8), so the cross correlation may indicate propagating disturbances or phased response to indirect wind effects such as upwelling and surges. In all these examples, the data are adequate only to illustrate lead/lag relationships, but fall short of providing a f inn basis for isolating the underlying dynamic cause.

3.3.5.2 Cross-isobath

Only one example, from 1984, provides a basis for cross-isobath comparisons in the nearshore area. In this case, L34 U-component, leads that of L32 by 12 hours (cross correlation of +0.37) and by 52 hours (cress correlation of +0.41) (Figure 3-39) . The cress correlation thus provides come confirmation of the presence of a 35 to 45-hour period signal.

On the basis of existing data, the implication is of a disturbance propagating slowly onshore from L34 to L32, about 6 km apart. One possibility is a slow meandering of the mean eastward alongshore flow.

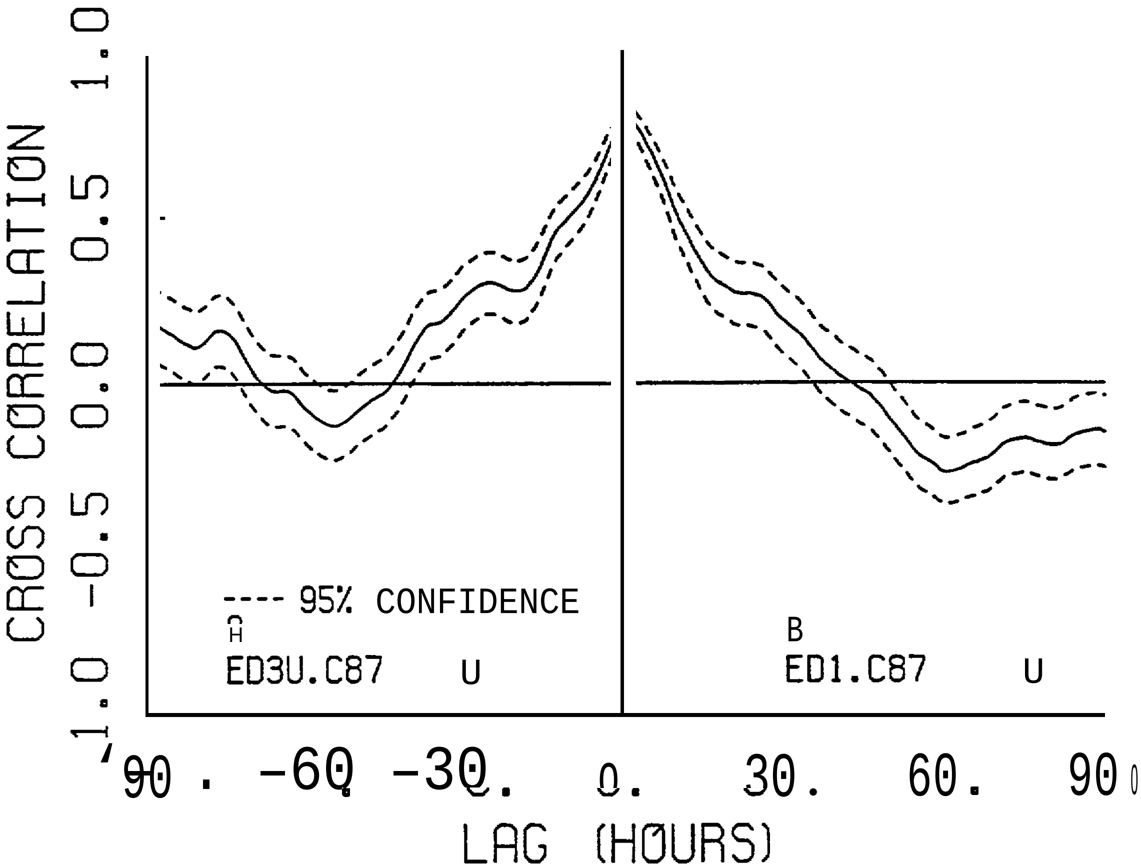


Figure 3-38. Cross correlation between U-component currents at ED3upper and EDl, l987. For positive lags, ED3 upper leads.

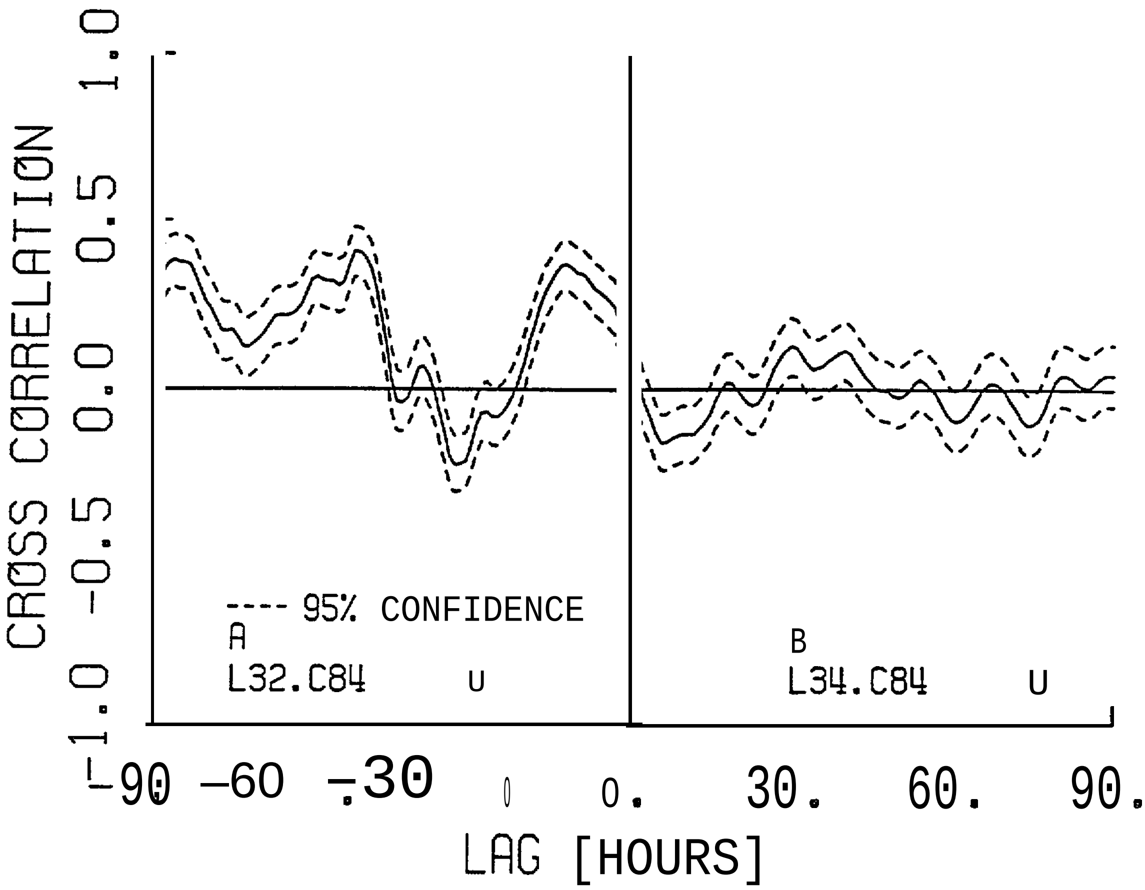


Figure 3-39. Cross correlation between U-component currents at L32and L34, 1984. For positive lags, L32 leads.

4.0 INTEGRATION OF RESULTS WITH THE BEAUFORT SEA MESOSCALE CIRCULATION STUDY (BSMCS)

4.1 METHODS

4.1.1 Data Manipulation

BSMCS data were obtained from NOAA PMEL, Seattle, Washington, and were converted to NODC format prior to using the data analysis programs. Since the data were presented at a one-hour interval, no subsampling was done. Because the data records were in excess of a year long, the BSMCS data were truncated to approximately the same length as the nearshore data records in order to save file space and scan time on the computer.

4.1.2 Selection of Data Sets for Analysis

4.1.2.1 BSMCS Data

The BSMCS data sets chosen for analysis with nearshore Current records were 1987-1988 MB4B-1 and MB2B-1, approximately 73 km and 82 km, respectively, NNE of Prudhoe Bay. Current record MB4B-1 sensor depth was 52 m in water 60 m deep, and MB2B-1 sensor depth was 72 m in water 185 m deep. These current records were coincident with the summer 1987 Endicott Environmental Monitoring Program. No other BSMCS data corresponded in time with available nearshore data records. Other 1987 BSM data records were about 230 km west or 160 km east frcm Prudhoe Bay and were not used in this analysis. Data from MB4B and MB2B were considered much more useful in making onshore/offshore current comparisons.

4.1.2.2 Nearshore Data

Data from mooring ED2 represented nearshore currents in the nearshore/offshore analysis. The choice was made on the basis of record length and location outside of nearshore Causeway systems to the east and west of Prudhoe Bay. In view of the high correlation between ED2 and ED1, the only other nearshore record of suitable length and location, the use of both was considered redundant.

4.2 SUMMARY AND ASSESSMENT OF DATA

4.2.1 BSMCS Data

Current record MB4B-1 spanned 03 April 1987 to 30-1988, easily bracketing the 1987 nearshore current records. Current record MB2B-1 spanned 05 April 1987 to 04 April 1988. Both were judged to be of high quality and appeared to contain no missing data. Figure 4-1 shows these two mooring locations, and Table 3-5 lists general details.

4.2.2 Nearshore Data

Description of the nearshore data (1987 ED2) appears in Section 3.2.5.

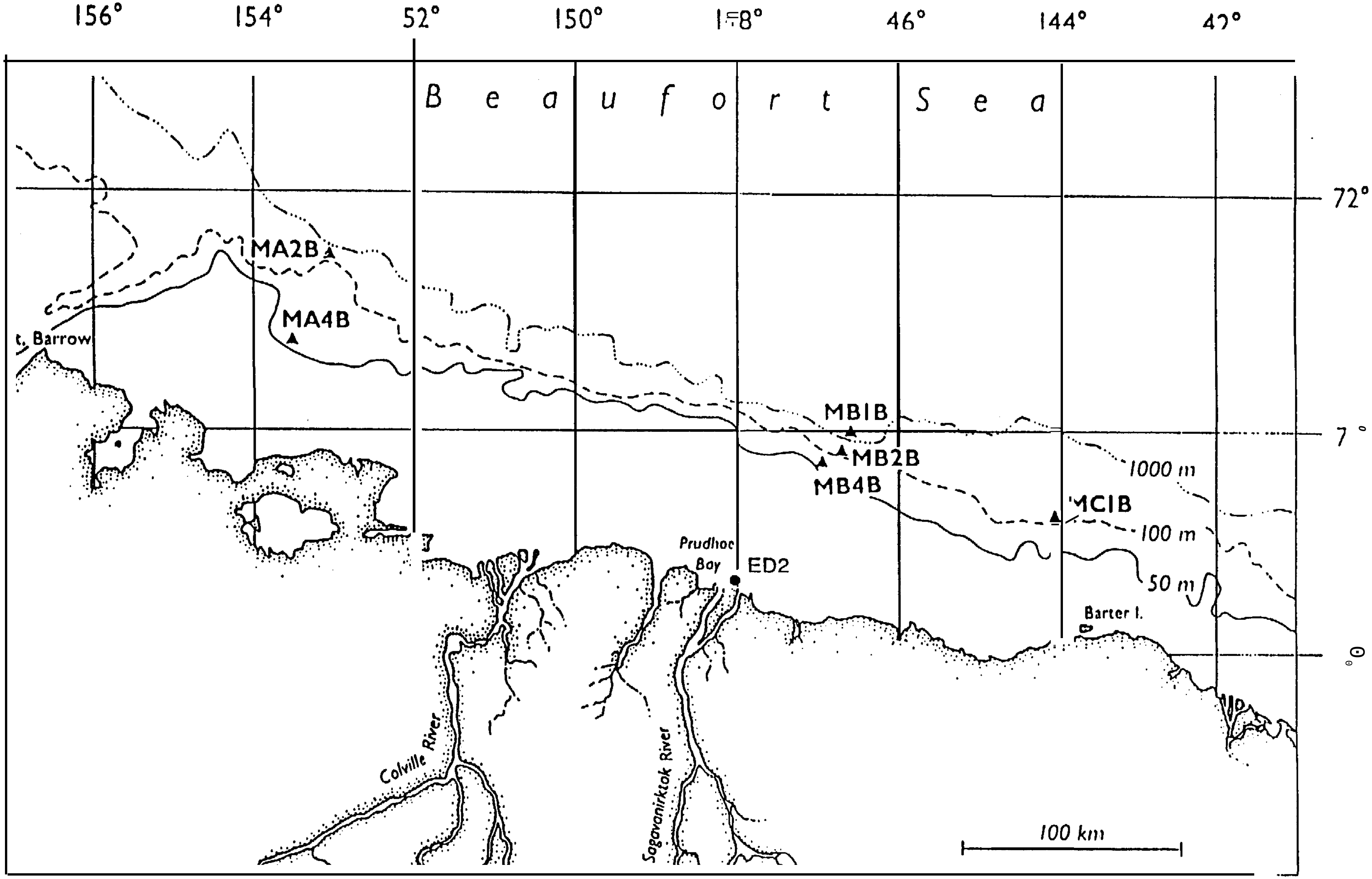


Figure 4-1. Location of 1987 current meter and meteorological data records selected for nearshore/offshore analysis and integration (Aagaard et. al. 1989).

4.3 RESULTS AND DISCUSSION

4.3.1 Wind and Offshore Currents

Resolution Island winds were well correlated with MB4B U-component (Figure 4-2). The maximum correlation was +0.69 with wind leading by eight hours, and the two remained significantly correlated about 45 hours either side of the maximum. Because of the depth of MB4B, it is unlikely that direct wind forcing is a significant source of current motions, but rather, the correlation likely represents the joint influence of large-scale atmospheric pressure distribution on both currents and wind.

In comparison, cross correlation showed MB4B U-component leading MB2B by 28 hours at the maximum correlation of +0.60. Considering that MB4B and MB2B are separated by only about 9 km, a phase difference of 28 hours is surprising.

4.3.2 Nearshore and Offshore Currents

The maximum correlation between currents at ED2 and MB4B was +0.65, with ED2 leading by six hours (Figure 4-3). This is consistent with previous correlations between wind and currents at ED2 and MB4B. The two time series remain significantly correlated within about 45 hours either side of the maximum. The maximum correlation between ED2 and MB2B was +0.57, with ED2 leading by 43 hours . Both results indicate significant correlation between nearshore and off shore currents, but do not suggest an explanation of the underlying cause.

Coherence and phase calculation between U-components of ED2 upper and MB4B-1 show a pronounced coherence peak at 0.028 cph, which corresponds to a period of 35 hours (Figure 4-4). The phase difference is about three hours, in rough agreement with the lag of six hairs at maximum cross correlation. The average of phase difference over the six lowest frequencies (each itself a linear average of five successive values) is slightly less than seven hours. The near agreement with the lag for maximum cross correlation suggests that low frequency motions clearly dominate the common nearshore/offshore signals.

Interestingly, a 37-hear period was identified in ED2 upper U-component autospectrum, as well as others. That period also appears clearly in the MB4B-1 U-component autospectrum (Figure 4-5). Incidentally, so does a peak at period of about 4.5 to 5 days. The five-day period is apparent in the MB2B-1 autospectrum, but the 37-hour signal is much less distinct. Aagaard et al., 1989, also identified the 4.5- to 5-day signal and speculated that it might represent an eastward-propagating trapped wave. whether or not the 37-hour signal has a similar explanation requires further work to determine beyond speculation. The period seems too short to be attributable to purely meteorological causes.

Cross correlations and spectra serve to establish the strength of nearshore-to-of f* relations and potentially identify major periodicities of common signals. However, the current meter data, in themselves, speak only weakly to the issue of momentum exchange and not at all to that of mass exchange between the nearshore and offshore circulation.

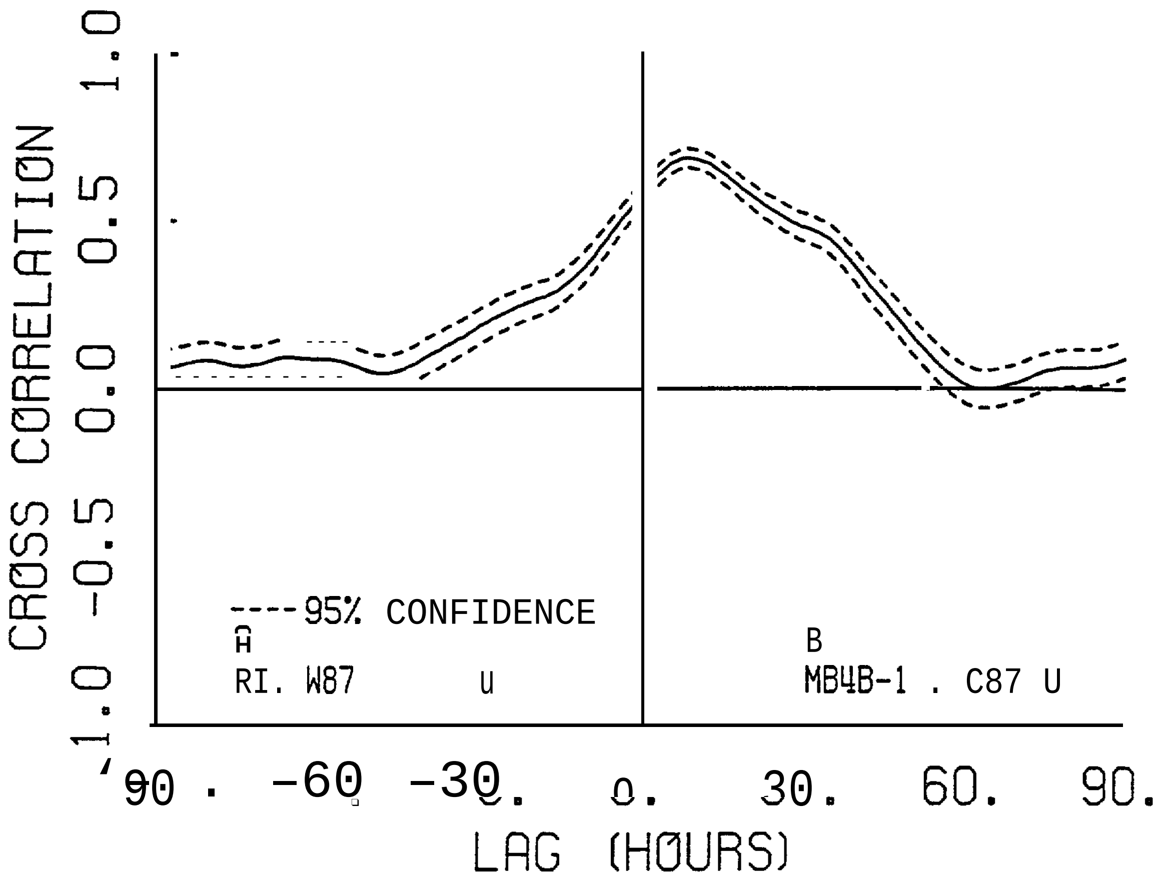


Figure 4-2. **Cross correlation between U-components of Resolution Island wind and MB4B-I currents, 1987. Wind leads for positive lags.**

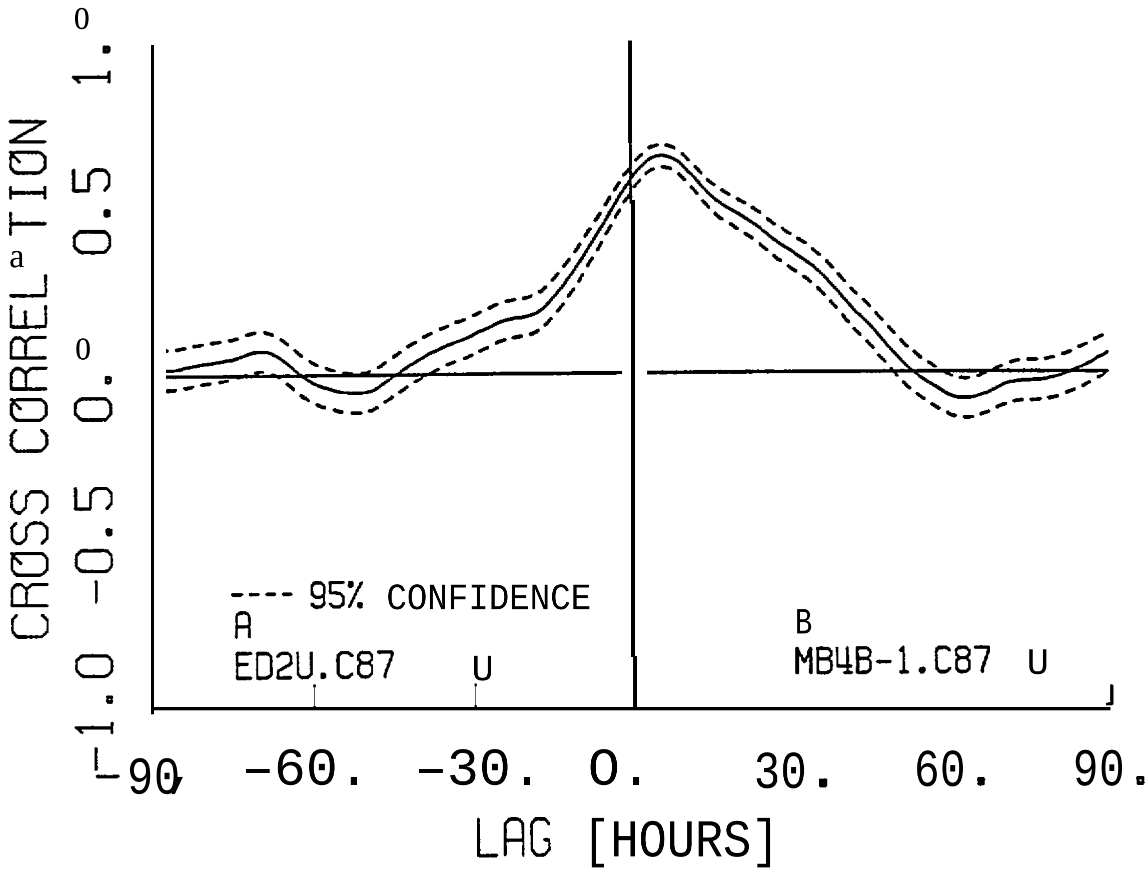


Figure 4-3. Cross correlation between U-component currents at MB4B-1 and ED2 upper, 1987. For positive lags, MB4B-1 leads.

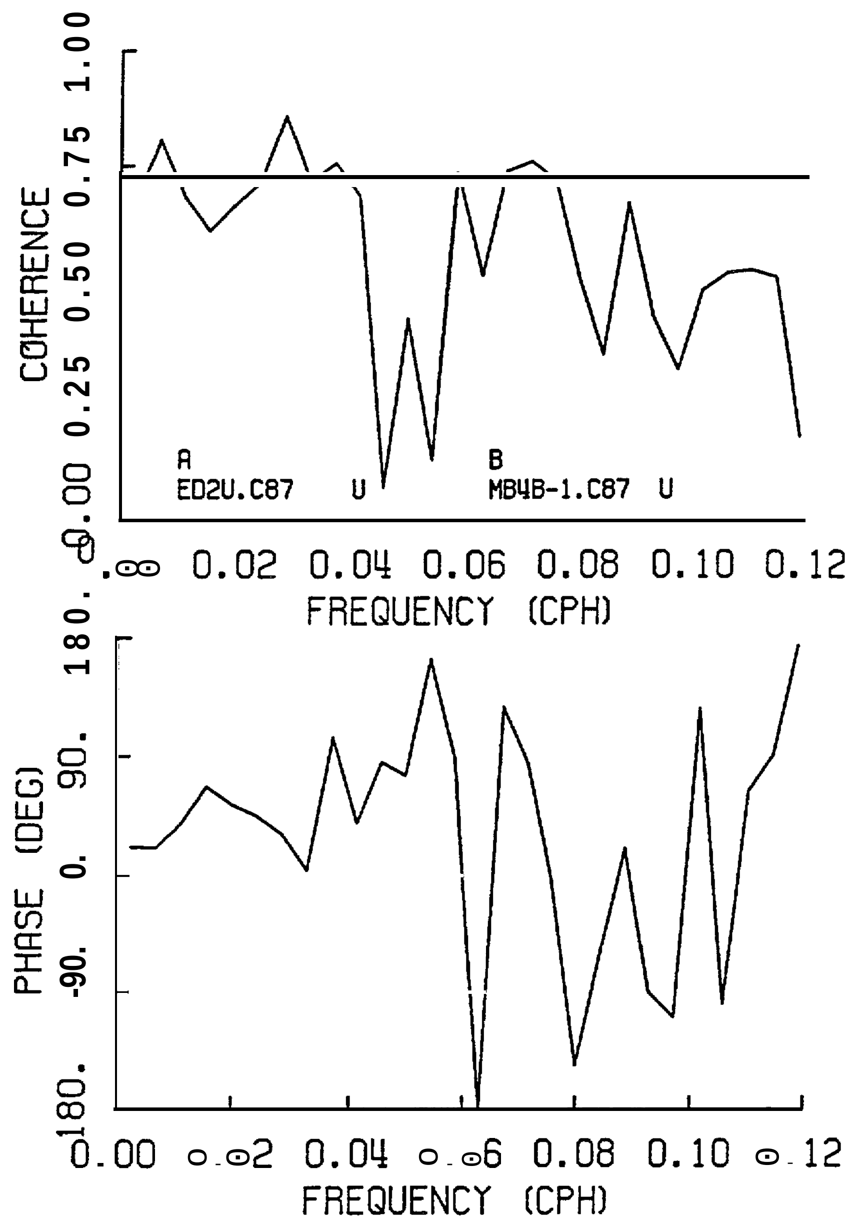


Figure 4-4. Coherence and phase between U-component currents at ED2 upper and MB4B-1, 1987. Positive phase indicates ED2 upper leads.

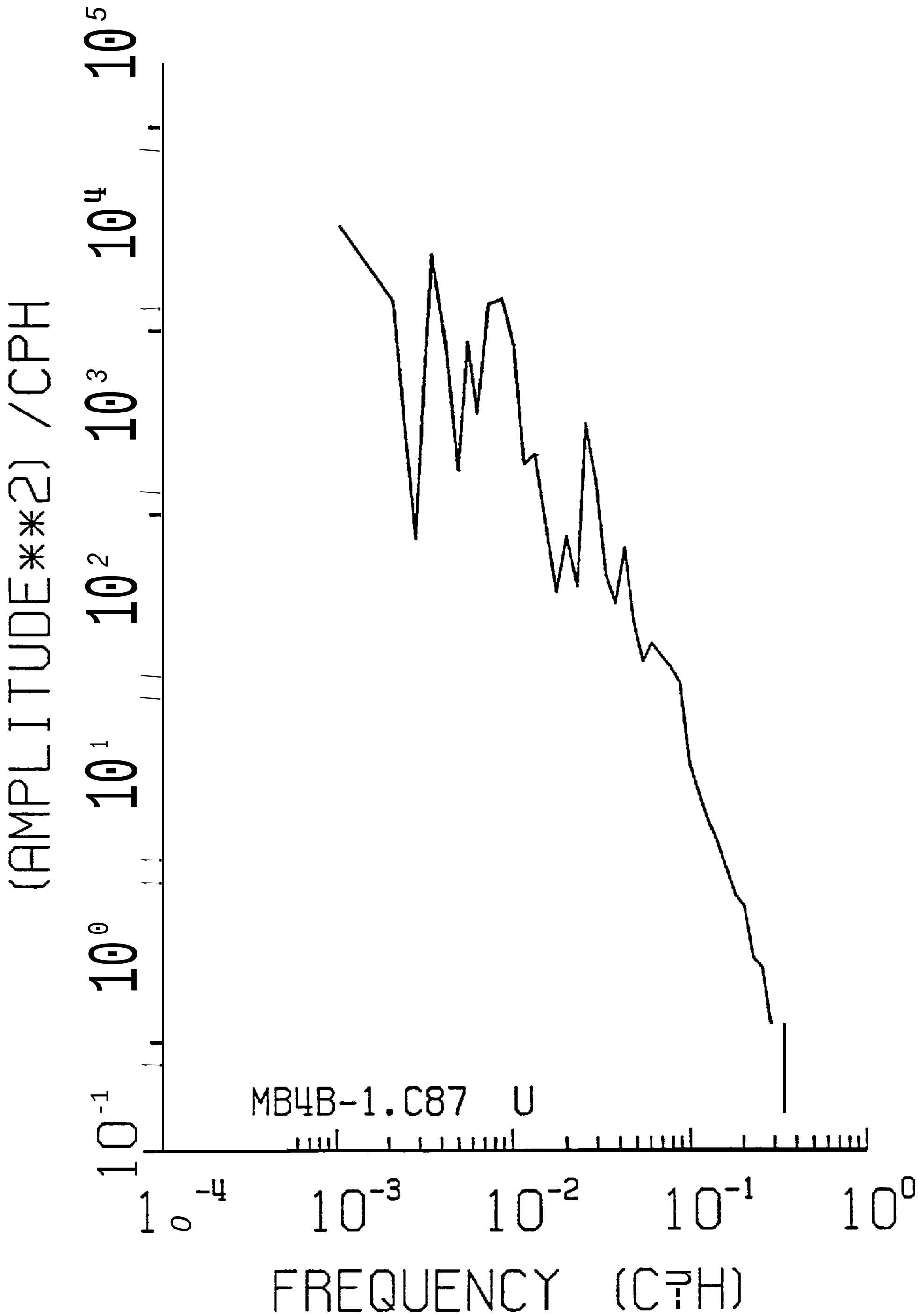


Figure 4-5. Autospectrum of U-component MB4B-1 currents, 1987.

5.0 COMPREHENSIVE SUMMARY

5.1 DATA IDENTIFICATION, DOCUMENTATION, COMPILATION, AND EVALUATION

The objectives of this task were: (1) to identify, document, and summarize all available information on historical data sets collected in the nearshore Alaskan Beaufort Sea region; and (2) to compile and evaluate the actual data from these historical data sets to the maximum extent possible.

This task began with a comprehensive review of oceanographic literature, project reports, data reports, and existing published data inventories. Direct inquiries were also sent to appropriate investigators, agencies, academic institutions, and private organizations known to have conducted studies in the region. Through these means, a total of 56 distinct project data sets encompassing physical oceanographic data from some part of the study area were identified. For each data set, documentation on where, when, why, how, and by whom individual data sets was acquired. Data types documented included current meter (moored and profiling), Lagrangian drifter, hydrographic (temperature and salinity), sea level (tide gauge), and meteorologic.

After the data sets were identified and documented, the compilation phase began, wherein all available historical data were obtained, organized, and reformatted (into standard NODC formats). A considerable volume of data was obtained from NODC via direct computer transfer from NODC's archival system to an Ebasco Environmental 386 microcomputer. Another large volume of historical data from the Prudhoe Bay/Stefansson Sound region already on hand in the Ebasco Environmental data archives was transferred into the project data base. A number of smaller data sets obtained from individual investigators or from optical scan-digitization of hardcopy tabular data listings in reperk comprised the remainder of the project data base.

Of the 56 documented data sets, only 29 (sane of these incomplete) were available for acquisition and subsequent analysis. Despite additional efforts to track down and acquire the missing data sets, many remained unavailable due to proprietary restrictions, inability to locate the original investigators, or inaccessibility of the original data.

Formal evaluation of the data quality associated with each data set proved to be impractical, due to the unavailability of a large number of historical data sets, combined with incomplete documentation on experimental methods, data processing, and quality control on many others. During the Course of the data analysis task, an evaluation was made of each data set used, and any apparent data quality problems were noted.

One recommendation arising from this task is a suggestion that government funding agencies be more diligent in ensuring that oceanographic data collected under public funding be submitted to NODC. Furthermore, we recommend that if possible, regulations be implemented to require submiion to NODC of any data collected by private concerns (e.g., oil companies) operating under agency permits. In the latter case, confidentiality could be stipulated for a specified time period, after which the data would become publicly available.

5.2 DATA ANALYSIS AND INTERPRETATION

Nearshore current records (depths <20 m) from 1982 and 1984-1989 were selected and analyzed using statistical and spectral techniques. Corresponding meteorological data for the various years were also obtained and used in the investigation of the relation between nearshore currents and wind.

Linear regression indicated that wind accounted for about 40 to 50 percent of current variance at current meter depths of 3 m or less. The percentage of explained variance of currents measured at sensor depths greater than 3 m was generally 10 percent or less, although two exceptions were noted in 1987 where the percentage of explained variance was as high as 35 percent. Density stratification, which itself is strongly influenced by wind direction and persistence, appears to be an important factor in the relation between direct wind forcing and deeper currents in the nearshore area.

Nearshore currents consistently lagged wind by one to three hours. Cross correlation coeff icients between major-axis components (U-components) of wind and currents averaged 0.69 but ranged as high as 0.91 for one case in 1987. Correlation coefficients between minor axis components (V-components) were typically between -0.4 and zero and decayed within lags of about 10 hours. Coherence and phase calculations between wind and current show that the major contribution to high correlation was at low frequencies, generally less than 0.02 cph. Current speeds were 2.7 percent of wind speed or less for all wind/current analyses, and the indraft angle between wind and currents was meaningless because of rectification of currents in the alongshore direction.

The vertical relation of currents at #e same mooring location varied markedly between 1985-1987. Maximum cross-correlation coeff icients between current records at depths of 2 m and 4 m were 0.64 and 0.91, respectively, in 1985 and 1987. These values occurred at one to two hours lags in 1985 and zero to one hour in 1987, with the shallower currents leading in both cases. Stratification appeared to be a factor in - difference. In contrast, the V-component cross correlation functions were only slightly different from zero, although a tidal fluctuation was obvious in the plot. Analogous coherence and phase calculations between the V-components of the currents at 2 m and 4 m for 1985 and 1987 were similar, implying that variance along the minor axis is a weaker function of depth or stratification than variance along the major axis direction.

There was notable vertical shear in currents at location CB6 in Camden Bay in 1989. Vector-average currents at location CB6 were east-southeastward in the upper part of the water column and north-northwestward one meter above the bottom. Vector-average wind was toward the south-southwest. Thus, bottom currents were primarily in the same direction as wind, but currents nearer the surface were in rough apposition to the wind. Wind explained less than 30 percent of the current variance at both depths. At the same location in 1988, currents 1 m above the bottom were eastward, but vector-average wind was approximately the same as in 1989. The implication is that local dynamics influenced currents at location CB6 in 1989. circulation probably reflects recirculation in Camden Bay and fluctuations in buoyancy input due to freshwater influx. Cross correlation and coherence and phase calculations between wind and CB6 currents and between upper and lower CB6 currents in 1989 suggest the possibility that localized dynamic factors in Camden Bay dominate wind effects in determining circulation and vertical shear in Camden Bay.

Autospectra indicate the presence of low-frequency signals in the U-component of nearshore currents. While the spectra exhibit general energy content throughout the band of frequencies less than about 0.02 cph, there is a strong hint of identifiable signals at frequencies of 0.007 cph (6-day period), at 0.0078 cph (5.3-day pied), and at 0.0087 cph (4.8-day period). These are all in the range of frequencies likely attributable to wind forcing, but data are not comprehensive enough to conclude that no other dynamic mechanisms contribute. These signals are apparent in some years, but not universally in all the years analyzed. The broadband nature of wind forcing complicates the Conclusive identification of any low-frequency signals.

Semi-diurnal tidal signals are particularly apparent in V-component current autospectra, although closer inspection shows comparable tidal energy in the U-component spectra that is masked by the general concentration of energy at low frequencies. Overall, the energy at tidal frequencies is a small fraction of the total energy in current motions.

Autospectra also indicate the year-to-year presence of a signal at frequencies of .029 to .022 cph (35-hour to 45-hour period). In one case, the spectrum of corresponding wind data also indicated a peak in approximately the same frequency range, while other wind spectra contained no similar peak. one possible explanation is a wavelike disturbance propagating alongshore, but a conclusive explanation awaits an experimental program designed to identify such phenomena.

Comparisons between the orientation of local isobaths and principal axis directions for currents suggests strong influence of bottom topography and proximity to coastline in steering currents alongshore. This is the case even when prevailing wind had a significant cross-isobath component. For two examples from 1985 and 1987, the principal axes of the deeper currents tended to be about 25 degrees offshore of the shallower currents. The difference may reflect the influence of layered-f low effects or friction near the bottom.

Cross correlations generally indicated that westernmost currents led currents farther east. This is likely related to the mean eastward flow in the nearshore area.

Interpretation of the analvtical results is complicated by the fact that wind forcing is a broadband phenomenon and is aperiodic, for the most part. This means that spectral investigations can rarely yield conclusive results. It also means that analyses of successive segments of a given data record may yield results that differ markedly from each other and from analyses using the entire record length. Furthermore, the contributions of other potential dynamic mechanisms to observed currents may overlap those of the wind, making discrimination between them cliff icult, if nut impossible without specific experimental design.

5.3 INTEGRATION OF RESULTS WITH THE BSMCS

Only during the open-water season of 1987 did available nearshore and offshore current measurements (BSMCS) coincide, so the number of data records available for nearshore/offshore comparison was limited. Those offshore current records closest to the location of the nearshore current records were chosen. Other offshore current records 230 km to the west and 160 km to the east were excluded under the assumption that comparison of ~/offshore current records with the smallest spatial separation would yield the most representative results.

The maximum correlation between nearshore (ED2) and offshore (MB4B-1) U-components was 0.65 with the nearshore currents leading by six hours. Corresponding coherence and phase calculations showed a distinct peak at 0.028 cph (35-hour period) with nearshore current leading by three hours. Low-frequency components are the primary contributors to the correlation between nearshore and offshore currents.

Resolution Island wind was also well correlated with MB4B-1 U-component current (0.69 with wind leading by eight hours). This is more likely due to wind and currents both responding to large-scale atmospheric pressure distributions rather than direct wind forcing of currents at a depth of 52 m at MB4B-1.

Autospectra of U-component currents indicated spectral peaks at about 0.027 cph (37-hour period) for both MB4B-1 and ED2U in 1987. This frequency is virtually the same as that apparent in coherence and phase calculations, suggesting a common mechanism coupling both the nearshore and offshore areas.

6.0 RECOMMENDATIONS

This section contains some brief recommendations regarding data acquisition/archiving as well as the nature of future oceanographic efforts in the region.

This study found that only about half of the historical data sets known to have been collected in the region were available for general use. This may be attributed to several factors. First, with respect to the incompleteness of the data holdings at NODC, it must be realized that in many cases the investigators were under no obligation to submit final data to that facility. In cases where such a requirement did exist (as a stipulation in some government funding agency contracts, for example), the funding agencies were apparently not diligent in verifying the data transmittals. The case of OCS/MATTHEWS 1977-81 (see section 2.2) is an apparent case in point. Understandably, both investigators and funding agencies assign a high priority to the collection and analysis of data and the reporting of scientific results. Data archiving and transmittal to NODC is often - last, and by perception, least important task of any project. A second problem is the unavoidable circumstance of personnel turnover. The departure of a principal investigator, graduate student, or key data manager before project completion strongly reduces the chance of orderly data archiving and transmittal. The inaccessibility of proprietary data sets for many years (see section 2.2) is a third reason for gaps in the available archived data base. By the time the proprietary restriction is lifted from a data set, the original data may be lost or degraded, and the investigator may be unlocatable.

We present two recommendations with respect to the data accessibility question. First, we suggest that stronger emphasis be placed on ensuring the submission of data to NODC in all projects funded by public agencies. Second, we suggest that a mechanism be put in place whereby data collected under private funding, but associated with government-regulated activities (e.g., permitted exploration and development activities), be required to be submitted to NODC in a timely fashion. In the latter case, it could be stipulated that the data shall remain confidential for a specified amount of time, after which it would become publicly available. At least in such a system, the data would not be ultimately lost.

One of the apparent impediments in characterizing the relation between wind and nearshore currents and between nearshore and offshore currents is the absence of oceanographic data between roughly the 10-m and 100-m isobaths. The obvious difficulty is seasonal encroachment of ice and probable damage or loss of moored instruments. Data from this segment of the shelf are necessary to investigate the transition between nearshore and offshore regimes, which likely involves transition from primarily wind-forced to ocean-forced dynamics. This is not to say that the realms of influence do not overlap, but rather that the degree of influence changes. Whether or not the change is abrupt at a particular depth contour, for instance, or gradual is not within the resolution of existing data.

In order to investigate dynamic processes, concurrent moorings separated both alongshore and offshore are necessary. This allows identification of propagating disturbances as well as determination of phase speeds, wave-lengths, and possibly, cross-isobath structure. continuation of data recording to include ice-covered intervals as well as open-water intervals is desirable as a means of looking at seasonal and annual circulation patterns.

Another approach to supplementing observations is to apply computer models to the shelf and slope regions of the Beaufort Sea coast. While such model investigations could nut be expected to be conclusive, they might serve to provide preliminary indications of types of dynamic mechanisms supported by the topography, stratification, and external forcing that typify the area*

7.0 ACKNOWLEDGEMENTS

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